EAST PARK RESERVOIR
LIMNOLOGY AND WATER QUALITY STUDY

MEMORANDUM REPORT

NORTHERN DISTRICT

JUNE 1971

STATE OF CALIFORNIA—RESOURCES AGENCY RONALD REAGAN, Governor

DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT
2440 MAIN STREET
P.O. BOX 607
RED BLUFF 96080

June 21, 1971

Mr. Frank L. Miller, Chairman
Board of Supervisors
County of Colusa
546 Jay Street
Colusa, California 95932

Dear Mr. Miller:

The Colusa County Board of Supervisors adopted a resolution on February 17, 1970, that Colusa County join with the State Department of Water Resources in a study of the East Park Reservoir drainage basin. The purpose of the study was to determine the possible effect that proposed urban development in the drainage will have upon the waters of the reservoir. This memorandum report presents the data and conclusions resulting from that investigation.

The Department developed and directed the study with the assistance of an advisory board consisting of representatives from Colusa County; the Orland Unit Water Users Association; the California Regional Water Quality Control Board, Central Valley Region; the U. S. Bureau of Reclamation; and the Water Quality Office of the Environmental Protection Agency.

The areas we investigated were the geology, soils, and hydrology of the basin; present development and use of the land on the watershed; the quality of the ground and surface waters; the physical, chemical, and biological features of the reservoir; and the present nitrogen and phosphorus levels and their sources and disposition within the reservoir. The primary source of the nutrients, nitrogen and phosphorus, is natural runoff with almost negligible amounts contributed by agricultural drainage and domestic wastes.

The study showed that East Park Reservoir is, biologically speaking, a productive reservoir and rated as an excellent bass-producing reservoir. However, the presence of blue-green algae in relatively large numbers and volumes indicates that the use of the water for domestic purposes without treatment might already be restricted,

although the algae has apparently not reached nuisance proportions as far as aesthetic conditions that affect recreation are concerned.

That the situation is not at problem levels now is due in part to the fact that the reservoir is presently operated in a manner that allows the trapping and discharging of a major portion of the nutrients before they can be recycled.

Our conclusion is that if the reservoir continues to be operated as it has been during 1970, if additional septic tanks and leach fields are adequately designed to receive the expected loading without permitting the effluent to migrate to the surface, and if the waters continue to be used for their present purposes, then no adverse effect would be expected on the recreational use of waters of East Park Reservoir until the phosphorus contribution to the watershed is equivalent to a permanent population of 760 people.

Copies of this report are being transmitted to the members of the advisory committee and other interested parties.

Sincerely yours,

Gordon W. Dukleth
District Engineer
Northern District

Enclosure

cc: Members of Colusa County Board of Supervisors

Harold L. Peterson
Edwin G. Ross
Robert J. Swallow
C. Martin Wilmarth

EAST PARK RESERVOIR DRAINAGE BASIN
WATER QUALITY INVESTIGATION
COLUSA COUNTY

MEMORANDUM REPORT

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SUMMARY AND CONCLUSIONS

East Park Reservoir is located in the foothills of the coastal range of mountains in the northwestern corner of Colusa County. Impounded by 139-foot high East Park Dam, it stores the flow of Little Stony Creek in a reservoir that contains approximately 49,000 acre-feet of water with a surface area of 1,820 acres.

The drainage basin is mostly mountainous, with over 90 percent of the area classified as having no soil mantle or having sub-soils with restricted or no internal drainage.

There has been little development on its drainage basin, and the major use of lands is for livestock production with non-irrigated alfalfa and dryland grains being the major crops. Future development is most likely to occur in areas at the lower elevations where the terrain is more suitable and where soil has built up.

No firm water supply has been developed above the reservoir. The surface runoff is seasonal, with the streams rapidly dwindling to minor or no flows after the winter storms have ceased. There are no extensive ground water bearing formations within the drainage basins, and ground water development is minor; however, wells are the source of almost all of the water used for domestic and stock purposes. Most of the producing wells are less than 100 feet in depth and have yields of less than 20 gallons per minute.

The chemical quality and character of the ground and surface water is influenced by the different geologic rock belts that it comes in contact with. Although the water quality of the streams is generally suitable for livestock and domestic purposes, the quality of the ground water produced from wells varies greatly.

Some springs in the area have been developed, but they generally discharge highly mineralized waters; one of these, Stites Springs, located southeast of Ladoga, produces water with sulfate concentrations of 462 milligrams per liter.

Surface streams, being responsive to the precipitation, have better quality water. During the winter when over 90 percent of the runoff occurs, the dissolved chemical concentrations are low. As the flow recedes, the concentrations increase. During the summer, the values are highest as almost all flow is due to accretions from the soil mantle or springs. The quality of surface water in each tributary is slightly different. Dissolved chemical concentrations vary according to the runoff to drainage area ratio with the water from the high runoff ratios being of better quality. However, water flowing from the western portion of the drainage basin is of a different character and is of better quality than water flowing from the eastern portion.

The surface waters are generally classified as good for most beneficial uses, except for the water draining from the eastern portion of the

drainage basins which contains dissolved hardness-causing compounds that would have to be removed before it could be utilized for some uses. Also, some of these same waters contain high sulfate concentrations and could have a laxative effect on people not used to drinking them.

Fifty years of record show that the mean unimpaired inflow into East Park Reservoir is approximately 55,000 acre-feet per year. Little Stony Creek is the major tributary and contributes from 65 to 70 percent of the natural inflow to the reservoir. To supplement the inflow during dry years, water is imported to the reservoir via a feeder canal from Big Stony Creek. This import begins with the first runoff of the season and ceases when the reservoir reaches storage capacity.

The waters in East Park Reservoir are conserved for irrigation use downstream and the operation of the reservoir is dependent upon the irrigation requirements of downstream service areas.

East Park Reservoir itself is used very little for water contact sports, and recreation facilities have not been constructed around the reservoir. However, the reservoir has become an excellent warmwater fishery and over 39,000 visitor-days were recorded in 1967. To accommodate these visitors, some areas have been developed for day use.

Controlled releases from the reservoir begin in April or May and continue until storage is depleted in August or September. Releases are made through three low-level outlets, the uppermost being 40 feet below the surface when the reservoir is at full storage capacity.

The reservoir thermally stratifies during the warm summer months. This prevents circulation and mixing of the warm upper layer (epilimnetic) waters with the colder lower layer (hypolimnetic) waters. The loss of circulation and mixing prevents replenishment of the oxygen in the lower hypolimnetic that has been utilized in the oxidation or respiration process. With no oxygen present, hydrogen sulfide gas is produced, the rate of nutrient recycling from the bottom sediments increases, and the water is restricted from use by oxygen requiring organisms. Materials originally suspended in the epilemnetic waters, such as sediments or nutrients tied up in organic matter such as algae cells, settle into the hypolimnetic waters and can be removed from the reservoir along with the releases through the low-level outlets.

The chemical quality of water in the reservoir is influenced mostly by, and is similar to, the water in the Little Stony Creek drainage. It is rated as good for beneficial uses.

A good supply of nutrients flows into the reservoir each year. Inflow from October 1970 to April 1971 contributed to the reservoir more than 52,000 pounds of nitrogen and 18,500 pounds of phosphorus. The main source of nutrients is from the natural runoff of the watershed. Nitrogen fixation by aquatic organisms and recycling from the bottom sediments are the major secondary sources. Ground water accretion directly to the reservoir and agricultural and domestic waste sources are negligible.

This supply of nutrients is sufficient to produce a good level of aquatic biota containing a diversity of organisms. The presence of large numbers and volumes of blue-green algae in the reservoir waters, however, indicates that the reservoir is showing signs of producing algae blooms approaching nuisance levels.

That the volumes of blue-green algae are not at nuisance levels now is due in part to the present operation of rapidly drawing down the reservoir early in the year through the low-level outlets. This removes a major portion of the nutrients before they can be recycled.

If East Park Reservoir continues to be operated as it was in 1970, and if septic tanks and leach fields can be designed so that they can function properly without failing, development on the East Park drainage can be permitted until the yearly phosphorus contribution to the watershed is equivalent to a permanent population of 760 people. When this population figure is approached, or if any of the existing conditions in the reservoir change, such as a modification of the reservoir's operation schedule, a reevaluation of the effects on the reservoir will have to be made.

INTRODUCTION

Today's affluent society has created a demand for more leisure time activities and facilities. People are no longer content to spend all their non-working hours in the metropolitan areas where they live and work, but are looking for areas where temporary relief can be obtained from the pressures associated with restricted urban living.

A large number of these people are turning to more remote, less confining areas where land can be purchased or leased for summer homes. People nearing retirement age are also looking for areas to purchase or build retirement homes, areas where they can readily engage in activities that suit their fancy, where upkeep is minimal, and where taxes are not a heavy burden. The choice areas are usually located close to recreation facilities such as the ocean, the mountains, a lake, or a stream.

Such an area is located in the Coast Range foothills of Colusa County. There, a private corporation has purchased land near East Park Reservoir, one of the better warmwater fisheries of the State, and has begun developing and selling homesites on land that was previously sparsely settled and used only for grazing and dry farming.

The Colusa County Board of Supervisors, concerned about the environmental impact that such a development will have upon the area, and especially on the waters of East Park Reservoir, requested the Department of Water Resources to determine the effects that land development would have on the drainage basin and the waters of East Park Reservoir.

The Department and the County entered into a $15,000 cooperative study agreement, with each agency sharing equally in the costs. The agreement stated that the Department of Water Resources would specifically compile available data on the geology and the ground and surface water quality and hydrology of the East Park drainage basin. In addition, the Department agreed to determine the limnological characteristics of East Park Reservoir and also collect the data necessary to determine the present nutrient sources or losses from the reservoir. With the limnological and nutrient data, an estimate could be made on the effects that the proposed land development would have on the chemical and biological quality of the reservoir waters. A copy of this agreement is included in the appendix.

To advise and lend direction and technical support to the investigation, an advisory committee was formed with representatives from the County of Colusa, Orland Unit Water Users Association, U. S. Bureau of Reclamation, Water Quality Office of the Environmental Protection Agency, Central Valley Regional Water Quality Control Board, and the Department of Water Resources.

The Department of Water Resources is authorized to conduct this type of study under Water Code Section 226(b) which permits the Department to investigate both surface and underground water conditions in cooperation with any person or any county, state, federal, or other agency.

History of Development

During the early settlement of the Orland area, farmers diverted water from Stony Creek on an individual and sometimes piecemeal basis. In the mid-1880's, these farmers formed two irrigation districts in the Orland area so that facilities could be constructed for more reliable diversions. It was recognized that because of low summer flows, storage was needed to insure more uniform and adequate flows during all of the irrigation season.

The residents in the two water districts, unable to finance construction of the necessary facilities, combined to form a water user's association. This move permitted them to make application to have the upstream storage facilities constructed as a federal project under authorization of the Reclamation Act of 1902. To do this required that owners of land lying within the service area sell their land holdings in excess of 160 acres in plots not to exceed 40 acres, an agreement that affected more than 40,000 acres of land in the service area. After application, the engineering board for the Bureau of Reclamation recommended in 1906 that the Orland Project be constructed. This project included construction of upstream storage facilities on Little Stony Creek at the East Park damsite.

Construction of the dam, located approximately 4 miles upstream from the confluence of Stony Creek and Little Stony Creek, began in 1909 and was completed 12 months later in June of 1910. The spillway, which is separate from the dam structure, was completed about the same time. A large amount of spill the first year caused damage to the ravine which carries the spill back to the main stream. To prevent further damage, a reinforced concrete chute with guide walls was constructed in 1911.

Following construction, however, two consecutive dry years showed that runoff from the natural drainage area to the reservoir could not be depended upon to fill the reservoir every year. To correct this inadequacy, water was diverted to the reservoir from the main stem of Stony Creek by constructing a diversion dam about 3 miles upstream from the community of Stonyford. A conveyance canal was then built leading from the diversion dam to East Park Reservoir discharging through a structure located approximately one mile south of the spillway structure for the reservoir. This diversion dam and canal, known as the Rainbow Diversion Dam and East Park Feeder Canal was constructed in 1914. At the same time that the feeder canal was constructed, the spillway crest for the East Park Dam was raised so that with removable stop logs in place, the reservoir capacity was increased 5,000 acre-feet from a capacity of 46,000 acre-feet to 51,000 acre-feet.

The East Park Dam and facilities compose one of the first storage projects built by the U. S. Bureau of Reclamation in the State of California.

East Park Reservoir

East Park Reservoir is created by a concrete arch gravity dam that is built about 2,000 feet below the confluence of Little Stony and Indian Creeks. This dam, 139 feet high from its lowest point, creates a reservoir having two arms, with the Little Stony Creek arm being approximately 3 miles in length and the Indian Creek arm about 4 miles in length at maximum storage.

The spillway for the reservoir is not an integral part of the dam but is located about one-quarter mile south. It is of concrete multiple arch construction, with a maximum capacity of 9,200 cfs and a crest elevation of 1198.18 feet.

The outlet works are located in the main dam and consist of a circular conduit 5 feet in diameter located in the lower part of the dam with the invert at elevation 1131.68 feet. This outlet conduit is controlled by a 4' x 5' steel gate on both the upstream and downstream sides of the gate chamber. The upstream outlet gate has been supplemented by two additional steel gates that have been installed in the chamber leading from the top of the dam to the outlet conduit. The uppermost of these two gates is located about halfway between the outlet conduit and the reservoir surface at full storage capacity at elevation 1156.68 feet. The second gate is located midway between these two gates at an invert elevation of 1141.68 feet.

A drainage conduit is located at elevation 1112.1 feet, and this limits the depth to which the reservoir can be drained, exclusive of evaporation.

The reservoir originally had a storage capacity of 46,000 acre-feet with an area of 1,707 acres. In 1914, storage capacity was increased by the addition of flashboards to the spillway crest. These flashboards permitted an additional 5,000 acre-feet of water to be stored, increasing the capacity to a total of 51,000 acre-feet with a surface area of 1,820 acres.

In 1962, a study on sediment deposition in the reservoir was conducted by the U. S. Geological Survey in cooperation with the Department of Water Resources. This survey determined that the average annual rate of accumulation of sediment in the reservoir from 1910 to 1962 was 0.38 acre-feet per square mile of drainage area, with a total contribution of sediment to the reservoir of 1,960 acre-feet. With this storage loss to sediment deposition, the total reservoir storage volume has been reduced to 49,000 acre-feet with the flashboards in and the reservoir at maximum elevation.

Present Use

Little urban development has taken place in the East Park Reservoir drainage area. A recent survey counted 62 dwellings on the

watershed, with about one-half being occupied. Ladoga, located on Indian Creek, is the only area where dwellings are concentrated. Total permanent population for the entire watershed is estimated at 100.

Land Use

A land use survey was conducted by the Department of Water Resources in 1959 which showed the predominant use of both irrigated and non-irrigated land within the drainage basin is for livestock production. Because of the lack of a firm water supply, non-irrigated pasture land and alfalfa and dry land grains are the only crops raised. There has been little change in the land use since that survey.

Recreation Use

Major recreation use of the reservoir is for fishing and is rated by many fishermen as one of the most popular bass reservoirs in California. Data furnished by the Bureau of Reclamation indicates that recorded annual recreation use has steadily increased from 18,600 visitor-days in 1960 to nearly 39,000 in 1967. About one-third of these recreationists come from the San Francisco Bay area. A survey by the State Department of Parks and Recreation in 1968 indicated that about 55 percent of the recreationists were overnighters or weekenders. About 75 percent of the use occurs during April, May, June, and July. Drawdown of the reservoir generally restricts recreation after August 1.

On October 28, 1970, the Department of Fish and Game conducted seining surveys in the reservoir and identified large and small mouth bass, blue gill, red ear and green sunfish, golden shiners, channel catfish, threadfin shad, and suckers. About every 10 years all of the water is drained from the reservoir to allow inspection of the outlet works on the dam. In the past when this has occurred, the Department of Fish and Game has taken advantage of the situation by saving the game fish, killing the less desirable species of fish remaining in the small pools, and replanting the reservoir with select species. Present plans are for this to be done again soon.

Black-tailed deer are found in the reservoir area and large numbers of ducks and geese use the reservoir as a resting area during the winter months.

GEOLOGY

Water quality investigations must consider the geology of the area under study because of its influence on the movement and quality of the runoff.

Tributaries to the East Park Reservoir drainage head on the east side of the Northern Coast Ranges. This range of mountains consists of folded and faulted sedimentary and metamorphic rocks that occur in northwest trending belts, and have been intruded in some areas by ultrabasic rocks. Since the tributaries flow eastward to the Sacramento River, they flow across these rock belts to reach the valley floor, though in some areas the streams follow along similar rock types for some of their length.

The drainage generally is divided into three belts of differing rock type and character, as shown on Plate 1. From west to east they are: (1) Franciscan Formation rocks, (2) ultrabasic intrusives, and (3) Great Valley sequence rocks. Locally, the Great Valley sequence rocks are overlain by alluvium and terrace deposits.

The westernmost belt, rising in elevation from 2,000 feet to 6,000 feet above sea level, consists primarily of intensely folded and faulted sedimentary and metamorphic rocks of Jurassic and Cretaceous ages that comprise the Franciscan Formation. This formation consists of various rock types including sandstone, shale, chert, and volcanic rocks, all of marine origin. Some of these rock types have been metamorphosed by heat and pressure to form greenstone, schists, phyllites, and slates.

The Franciscan Formation is bounded on its eastern limits by a northwest-trending, two-mile belt of ultrabasic intrusive rocks that have been mostly altered to serpentine. A major fault, the Stony Creek fault, and an unnamed paralleling fault separate the intrusive rocks on the west from the Great Valley sequence on the east.

The most eastern belt, rising from 1,000 to 2,000 feet above sea level, is characterized by north-trending marine sediments of moderately hard to moderately soft sandstone, shale, and conglomerate. All of these rocks, from the Stony Creek fault eastward, comprise the Great Valley sequence of upper Jurassic and lower Cretaceous ages. These stratified sediments are steeply tilted to the east and are locally faulted. The terrain exhibits low foothills, north-trending ridges and valleys with drainage patterns paralleling them. The more resistant tilted conglomerate and sandstone beds form the hogback ridges, and the softer intervening shale beds have been more deeply eroded to form valleys. The older rocks of the Great Valley sequence are located on the western side of the reservoir, and are in fault contact with the band of serpentine to the west. This area comprises a thick section of thinly bedded shales with thin lenses of limestone and lesser amounts of sandstone and conglomerate. East of the reservoir, the stratified layers of sediments in the Great Valley sequence become progressively younger and have a higher ratio of sandstone to shale than has the lower or older portion.

Soils

The soils information is presented to assist planners in determining the areas within the watershed that are most suitable for acceptance of effluent from septic tanks.

In June of 1948, the Division of Soils of the College of Agriculture, University of California, published a report on a study of the soils of Colusa County, including the soils in the East Park Reservoir drainage. Material for this section was taken from that report.

This soil survey consisted of examination, classification, and mapping of the soils in the field. The soils were classified into units according to their internal and external characteristics. These included their color, structure, porosity, consistency, texture, and content of organic matter, roots, gravel, and stone in the soil profile.

The soil units are classified into Recent alluvial, older alluvial, terrace, and upland soils.

In soils, the series is the most important unit and includes soils similar in characteristics and arrangement in the soil profile and developed from a particular type of parent material. The soil series are usually given names of places or geographic features near which they were first found, names like Corning, Zamora, Stonyford, or East Park.

Some areas of land, such as riverwash or bare rocky mountain sides, are devoid of fine soil. These areas are classified as miscellaneous. Plate 2 shows the location of these soils within the lower reaches of the drainage basin.

Recent Alluvial Soils

Recent alluvial soils generally have deep permeable profiles, are neutral in reaction, and are weathering from sedimentary alluvium. They have good surface drainage and generally good internal drainage. In the East Park drainage basin they are composed of the Chamisal, Yolo, and Zamora series. In this area, these are the best suited soils for accepting effluent from the leach lines of septic tanks.

The Chamisal series, covering about 1,000 acres, is found on the plateau immediately west of and adjacent to Ladoga (see Plate 2). This series has a deep permeable profile and is comprised of secondary soils derived from the old marine sediments transported from higher elevations and deposited in a terrace position. They are coarse textured and gravelly.

The Yolo series of soils is found along the Indian Creek Valley floor. It has been formed recently from transported material derived originally from sedimentary sandstones and shales with minor mixtures of materials weathered from local intrusive or metamorphosed rock formation.

The Zamora series is in the valley fill areas adjacent to and feeding the main stem of Indian Creek. This series has formed an alluvium

outwashed from areas of sedimentary rock sources and is deposited as broad, gently sloping alluvial fans, with generally smooth relief. Upper subsoil is slightly compacted with imperfectly formed structural units and other characteristics of recent deposition. Subsoils are often stratified with silty or gravelly deposits with slightly retarded internal drainage.

Older Alluvial Soils

Older alluvial soils are characterized by moderately compacted and fine textured subsoils which restrict free penetration of roots and water. The soils in the study area within this group are the Myers and East Park series. These soils will accept effluent from septic tank leach fields but not as readily as the recent alluvial soils. This means that additional area for the leach fields is necessary.

Myers series soils within the East Park drainage are located south of Ladoga between the valley foothills on the east and the Indian Creek alluvial plain. This series is secondary soils composed of the alluvium outwashed from the sedimentary rock sources in the adjacent foothills to the east. The deposit is fairly old and through physical and chemical weathering processes has formed moderately dense subsoil. Topography is very gently sloping and generally smooth relief with good surface drainage and slow internal drainage.

The East Park series soils occur in the lower Hyphus Creek drainage. This series has formed from weathered material that has been transformed from metamorphosed sedimentary and basic igneous rock sources. Most of the minerals appear to be basic igneous in character and contain a large percentage of serpentine. These soils have been deposited as a deep capping of valley fill over various consolidated strata. The soil is easily crumbled at certain moisture levels, but very sticky when wet. It forms large surface cracks when dry. The subsoil has a high colloidal content that is slightly to moderately compacted, and retards free penetration at any moisture level.

Surface drainage is good to excessive, but internal drainage is restricted.

Terrace Soils

Terrace soils are formed in those outcroppings of very old valley fill materials which were not buried by more recent alluvial deposits. They are very easily recognized by their reddish-brown gravelly surface horizons underlain at depth by a rich brown gravelly clay which very often is compacted to claypan hardness. Because of this, these soils will be restricted in their capability to receive effluent from septic tank leach lines.

The Corning series is the only series in the terrace soils found in the East Park drainage. It borders on the northwest of the Chamisal series and is also adjacent to Little Stony Creek in the lower reaches.

The Corning series has its origin in a wide variety of rocks which have been transported considerable distances and deposited in valley basins. They have been covered by more recent alluvium and are exposed as high terrace lands along the side of the valleys. Surface soils are loose and easily crumbled and are easily penetrated by roots and water. Subsoils are dense and fairly compacted with restricted drainage.

Upland Soils

Upland soils are sometimes referred to as primary soils as they are formed in place from the underlying parent rock. The upland soils in the East Park drainage are underlain predominantly by sedimentary rocks which are characteristic of the west side ranges of the Sacramento Valley. However, there is a group derived from basic igneous bedrock. These soil series, the Contra Costa and Lodo, occur in the upland soils.

The Contra Costa soils are located in the foothills to the east of East Park Reservoir and Indian Creek. They are shallow primary soils formed in place from the underlying slightly metamorphosed sedimentary sandstones, shales, and conglomerates. Because of the progressive removal of surface soil by erosion, profile development is rather shallow. Surface soil is generally a clay loam with a soft cloddy structure easily penetrated by roots and moisture. Subsoil is a slightly compacted reddish-brown clay that develops vertical cracking that permits roots and moisture to penetrate with only slight retardation.

Though drainage is good to excessive in both the surface and subsurface soils, septic tanks on these soils could create problems as the effluent, rather than be absorbed by soils, could migrate great distances along the cracks that have developed in the subsoil.

Lodo soils in the drainage are found between the coastal mountain range on the west and the valley foothills on the east. They are in a relatively narrow band running from Leesville north to Ladoga and on into Glenn County.

Lodo soils are formed in place from the underlying shale bedrock and are very shallow primary soils. Differences between surface and subsoil are absent or masked by the mixing of the shale bedrock with the soil mantle. Surface soil is a dull brownish-gray loam that is very loose and porous and varies in thickness from an inch or two to not more than six or seven inches in extreme cases. Subsurface soil, varying in thickness from 2 to 3 inches, may form between the surface soil and the parent bedrock,

but generally it is lacking or mixed with the surface and parent materials. The shale parent material is badly warped and folded to an undetermined depth.

Surface drainage is good to excessive with slight to excessive sheet erosion and gullying. Subsurface drainage is almost non-existent as there is generally no subsoil. Septic tanks can be located on these soils only with difficulty.

HYDROLOGY

Flow in the East drainage basin is seasonal and responds to and follows the pattern of precipitation. Though snowfall does occur at the higher elevations, it is generally not sufficient to form a snowpack that would contribute runoff into the warmer seasons.

Precipitation on the watershed varies from a mean of 18 inches per year at East Park Dam to more than 52 inches per year in the upper reaches of the drainage. Two rain gaging stations have been in continuous operation within the drainage area since 1936. These are located at the Cooley Ranch in the upper reaches of Little Stony Creek and at the dam tender's residence at East Park Reservoir. Figure 1 shows the total yearly precipitation measured at these two stations.

Plate 3, "Isohyetals and Surface Water Sampling and Water Measuring Stations", shows the distribution of precipitation on the drainage basin.

Ground Water

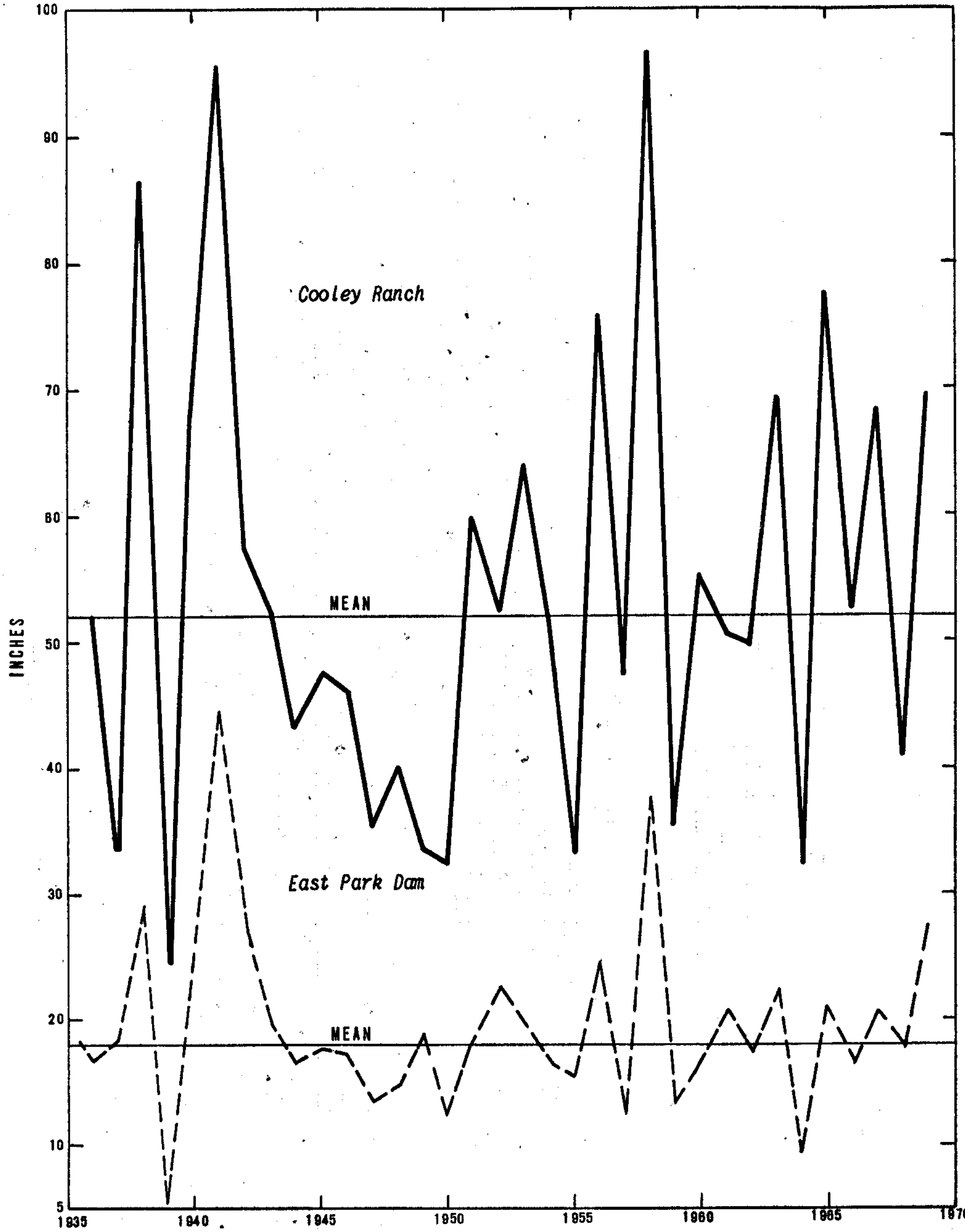
There appears to be no extensive areas of water-bearing formations within the drainage basin; however, limited water-bearing formations occur in the shallow alluvial plains along the streams and in the terrace deposits.

Logs of wells drilled in the area show most wells to be less than 100 feet in depth with yields that are less than 20 gallons per minute. There are also wells drilled throughout the area in which no water was found. Because of the apparent lack of ground water, or low yields from existing wells, development of the ground water is limited to domestic and stock use.

Some springs are found along the fault zones and they have been developed for domestic and stock watering use. Water from these springs is generally highly mineralized, their supply is not firm, and they generally dwindle to low flows during the late summer or fall months.

Surface Water

Flow in Little Stony Creek has been measured since 1908. Originally, a stream gaging station was located downstream from East Park Reservoir just before the stream joined Stony Creek near Stonyford. However, the control and accuracy of this station were not considered reliable and it was moved above the reservoir in 1966. The Department of Water Resources has made estimates of annual unimpaired flows into East Park Reservoir on a monthly basis for the 50-year period from 1910-11 through 1959-60. Because of the doubtful accuracy of the measured flow,



TOTAL YEARLY PRECIPITATION
EAST PARK DRAINAGE BASIN

inflow was estimated by using an area-precipitation ratio based on the gage for Stony Creek at Black Butte damsite near Orland. Based on this estimate, the mean unimpaired inflow to East Park Reservoir is 55,000 acre-feet per year.

Natural runoff from the drainage to East Park Reservoir was determined by the figures derived from the stream gaging station on Little Stony Creek and by installing stream measuring gages with recorders on Indian Creek and Squaw Creek. The remainder of the watershed runoff was estimated by using an area-precipitation ratio. Imported water was measured at the outlet structure from the East Park Feeder Canal. Inflow to the reservoir from October 1970 to April 1971 was estimated at 57,830 acre-feet of water. Almost all of the natural runoff is contributed by the four stream systems which have developed within the reservoir drainage basin. These are Little Stony Creek, Indian Creek, Squaw Creek, and Hyphus Creek. The measured and estimated inflow to the reservoir from all sources in tabulated form is shown in Table 1, "Inflow to East Park Reservoir from October 1970 to April 1971".

The location of the stream gaging stations is shown on Plate 3.

TABLE 1

INFLOW TO EAST PARK RESERVOIR
FROM OCTOBER 1970 TO APRIL 1971 - IN ACRE-FEET

Stream	Inflow in A.F.	Percent of Natural Inflow	Inflow to Drainage Area Ratio = AF/mi.^{2}
Little Stony Creek	33,200	68	678
Indian Creek	8,100	17	272
Squaw Creek	930	2	103
Hyphus Creek	2,750	6	550
Contiguous Area	2,500	5	227
Precipitation	1,120	2	
	48,600	100	
Inflow from Stony Creek via Rainbow Canal	9,230		
Total Inflow	57,830		

Little Stony Creek

The major tributary to East Park Reservoir is Little Stony Creek. This stream originates along the eastern divide of the Coastal Range and has a drainage area of 49 square miles. A stream gaging station has been maintained at this site by the U. S. Geological Survey since 1966.

This station, located approximately 2 miles upstream from the reservoir, measured a contribution of 33,200 acre-feet to East Park Reservoir from October 1970 to May 1971.

Indian Creek

Indian Creek is the major tributary to the east arm of East Park Reservoir. Composed of two stream systems, Indian Creek and Little Indian Creek, it has a drainage area of 29.8 square miles.

No permanent gaging station on Indian Creek has been established. For this study, a gaging station was installed at the bridge at Ladoga to measure the total flow from this drainage. This station was maintained until March when backwater from the reservoir necessitated moving it upstream to the first bridge south of Ladoga.

Squaw Creek

Squaw Creek originates in and drains the Sacramento Valley foothills on the east side of the drainage. Flowing into the eastern arm of the reservoir, it has a drainage area of 9 square miles. No permanent stream gaging station has been established on this arm; however, for the purposes of this study a temporary gaging station was established at the bridge crossing Squaw Creek just before the creek enters East Park Reservoir.

Hyphus Creek

Hyphus Creek flows into Little Stony Creek above its confluence with the west arm of East Park Reservoir. Draining the Coastal Range to the west, its headwaters are in the Franciscan Formation, though most of its 5-square mile drainage area is in the Serpentine Formation. No stream measuring gage was established on Hyphus Creek and streamflow was established by using the area-precipitation ratio.

Contiguous Area and Reservoir Surface

Runoff from land contiguous to the reservoir flows directly to the reservoir before joining any stream system. This area, plus the surface area of the reservoir, comprises approximately 11 square miles, which is equal to 11 percent of the total drainage. Runoff from the land area was determined by the precipitation-area method. In addition, precipitation directly on the reservoir surface was estimated at 1,120 acre-feet for the same period.

East Park Fedder Canal

The natural inflow to East Park Reservoir in some years is not sufficient to fill the reservoir. To insure that the reservoir is filled to capacity, water from Stony Creek, which is not tributary to the reservoir, is diverted to the reservoir through the East Park Feeder Canal.

Generally, there is no scheduled amount to be diverted from Stony Creek. The method of operation is to open the headgates and divert a portion of Stony Creek flow through the canal into the reservoir until full storage capacity is reached. To measure the amount diverted during the 1970-71 water year, a gaging station was re-established at the canal outlet structure to the reservoir. From October 1970 to April 1971, approximately 9,230 acre-feet entered East Park Reservoir from this diversion. The total natural and imported inflow to East Park Reservoir for the October to April period was 57,830 acre-feet.

Outflow

The present method of operation of the reservoir assures that the reservoir is filled to capacity by use of diverted water from Stony Creek via the East Park Feeder Canal. After the reservoir is full, the diversion from Stony Creek is stopped. Natural inflow then maintains a full reservoir until it is drawn down for irrigation.

Releases from East Park Reservoir are made depending on the need for irrigation use within the Orland Unit Water Users service area. The operation is coordinated with releases from Stony Gorge Reservoir located downstream.

Releases are generally made from Stony Gorge Reservoir first. However, the upper reaches of Stony Gorge Reservoir have filled in with fine-grained sediment deposits. When these extremely erodible deposits are exposed, they are easily picked up and placed in suspension by the inflowing relatively clear water released from East Park Reservoir. This causes Stony Gorge Reservoir and its releases to become highly turbid. To prevent this, the water in Stony Gorge Reservoir is held at a near full level and downstream demands are met by releases from East Park Reservoir until it is almost empty. Then the waters in Stony Gorge Reservoir are drawn down.

In 1970, releases from East Park Reservoir started on April 23 and continued until September 10. At that time, releases were stopped except for minor amounts needed to satisfy downstream water rights. The water surface was drawn down a total of 51.54 feet and on September 10 there was 2,454 acre-feet remaining in the reservoir. Based on this, 48,044 acre-feet of water was released or evaporated from East Park Reservoir in 1970.

WATER QUALITY

Natural waters are never completely pure. During their passage over or through the ground, they acquire a wide variety of dissolved chemicals or impurities. These impurities are seldom in large concentrations in the ordinary chemical sense; nonetheless, they can modify the chemical behavior or usefulness of the water's intended purpose.

Many tests are employed in the examination of water samples for very different and definite purposes, the essential purpose being to determine the fitness of the water for the use it is to serve. Some of these tests give direct information and some are inferential.

Most of the dissolved constituents in water are ionized to form positive ions (cations) and negative ions (anions), and so waters are classified, with respect to mineral composition, in terms of the predominant ions. The chemicals making up almost all of the dissolved minerals in natural water are calcium, magnesium, sodium, and potassium (which are cations) and bicarbonate, sulfate, and chloride (which are anions). Specifically, the name of an ion is used where it constitutes at least half of its ionic group, expressed in equivalents per million. Where no one ion fulfills the requirement, a hyphenated combination of the two most abundant constituents is used. Thus, a calcium-bicarbonate type water denotes that calcium constitutes at least half of the cations and bicarbonate represents at least half of the anions. Where calcium, though predominant, is less than half, and sodium is next in abundance, the name is modified to calcium-sodium bicarbonate. The concentrations of chemicals are determined on a weight basis and reported as milligrams per liter (mg/l).

Chemically pure water in liquid form has a very low electrical conductance. The more ionized chemicals per unit of water, the greater the capacity the solution has to conduct an electrical current and the higher the conductance value. The measurement of the specific electrical conductance of a sample of water is by inference, a measure of the dissolved chemicals in the sample.

Those organic and inorganic chemicals needed by primary organisms in the food chain to grow and reproduce their species are considered nutrients. Though there are a number of chemicals needed for biological growth, it is generally agreed that the principal elements needed to produce new protoplasm and cellular material are carbon, nitrogen, hydrogen, oxygen, phosphorus, and sulfur. The nutrients often considered to be the most significant ones limiting the growth of aquatic organisms in surface water are nitrogen and phosphorus. Nitrogen is usually found in the form of ortho-phosphate (PO_4) and total phosphorus (organic P plus PO_4). These are the only forms determined and utilized in this study.

Nitrate and ammonia concentrations were determined because they are quite soluble and can be readily used with about equal facility by aquatic organisms.

Organic nitrogen is that nitrogen which has been tied up or used in plant protoplasm or cellular material. It is formed and degraded by biological action and thus contributes to the fertility of the water. This contribution is either directly through uptake by the organism or indirectly through recycling by conversion to nitrate or ammonia by biological or chemical reactions.

Ortho-phosphate (PO_4) is the phosphorus that is in solution and is readily utilized by aquatic organisms. Total phosphorus is of great importance in that it is the reservoir that supplies the available phosphorus. There is no set relationship between total and available phosphorus because the ratio varies with season, temperature, and plant growth. Some forms are not readily released and others are recycled extremely rapidly.

There are some who think that carbon should be listed as one of the limiting elements; however, evidence indicates that carbon (in the form of CO_2) rarely becomes limiting in high alkalinity waters like East Park Reservoir except during excessive or massive blooms of algae -- something that has not been noted in East Park Reservoir.

Ground Water Quality

Twelve wells were sampled during the summer of 1970. No chemical or nutrient analyses were performed on the samples but electrical conductivity values were determined. These values and the well locations are included in Table 2.

TABLE 2

EAST PARK RESERVOIR DRAINAGE AREA
GROUND WATER
ELECTRICAL CONDUCTIVITY MEASUREMENTS

Well Number and Location	Use	Date	Temperature	pH	$ECx10^{-6}$
T17N/R6W-21R1	Domestic	4-30-70	65	7.3	951
-22N1	Domestic	4-30-70	64	8.2	241
-25D1	Domestic	4-30-70	59	7.8	1378
-26A1	Domestic	4-30-70	57	7.3	765
-26D1	Domestic	4-30-70	65	6.8	258
-26H1	Domestic	4-30-70	63	7.3	1015
-26J1	Domestic	5-11-70	60	7.1	897
-27F1	Domestic	4-30-70	65	7.4	372
-27F2	Irrigation	4-30-70	65	7.2	4052
-27G1	Domestic	4-30-70	65	7.0	342
-28B1	Stock	4-30-70	66	7.2	713
-36D1	Domestic	5-11-70	61	7.1	916
T17N/R5W-31L1 (Stites Spring)		5-11-70	192	6.9	1729

These data show the lowest conductance values of 240 micromhos from a well in the alluvial gravels of Little Stony Creek, through values from 765 to 1,375 micromhos in the wells along Indian Creek, to a high of 4,050 micromhos in a well pumped by a windmill that is located approximately 1-1/2 miles west of Ladoga.

For comparison, water supplies for the City of Williams have conductance values of 1,000-1,100 micromhos, and the City of Colusa water supply has values of 550-600 micromhos.

Stites Springs, located in the Indian Creek drainage, is the only spring that was sampled and analysed. In May 1970, a sample of water from this spring had a conductance value of 1,729 micromhos. Sampled again at the end of March 1971, the conductance of the water was 1,560 micromhos. Determinations were also made of the chemical and mineral constituents. These analyses show the water as having total dissolved solids of 1,120 mg/l with sulfate concentrations of 462 mg/l.

These high sulfate concentrations are undoubtedly coming from gypsum (calcium sulfate) deposits within the formation. Other than a laxative action toward new users, this relatively high concentration does not have any detrimental effect on man or animal; however, sulfates can be corrosive to concrete structures.

Surface Water Quality

Samples of runoff from different streams were collected and analysed for their chemical constituents in April 1970 and March 1971. These analyses are included in Table 3, "Mineral Analyses of Surface Water in East Park Drainage Area".

Little Stony Creek

Analyses made on a sample of water collected from Little Stony Creek show the water to be of generally good quality, with relatively low concentrations of dissolved minerals. Electrical conductance measurements made on samples collected at various flows show the quality of water entering East Park Reservoir to vary greatly depending on the flow. During the winter when over 90 percent of the runoff occurs, the conductivity values are low, ranging from 95 to 185 micromhos. As the flow decreases, the conductivity of the water increases. During the summer and fall, almost all flow is due to accretions from the soil mantle or springs. These waters are more mineralized and conductivity values increase to 850 micromhos.

Waters in this drainage flow across the two western geologic belts and into the eastern belt before entering the west arm of East Park Reservoir. The Franciscan and the ultrabasic intrusives are the principal sources of the dissolved minerals in these waters. Their mineral content classifies the water as a magnesium-calcium bicarbonate type that is low

in total dissolved solids. The calcium is derived mainly from leaching of the feldspars in the sandstones and some of the metamorphics, and the magnesium from the magnesium-bearing minerals in the serpentine or from mineralized springs.

Samples were collected and analyzed on a number of tributaries to Little Stony Creek in October 1970 and March 1971. Surface waters draining the Franciscan Formation in the upper reaches of the stream system are of good quality, having relatively low values of dissolved minerals. Conductivity values range from 165 to 278 micromhos. As these waters flow downstream to the lower elevations, they cross the more mineralized serpentine. Samples of water originating in the ultrabasic intrusives have conductivity values ranging from 580 to 697 micromhos. These waters are influenced not only by the minerals in the exposed rock formations, but also from highly mineralized springs or seeps that occur along the fault zones. During high flows these fairly highly mineralized waters are diluted and generally do not change the overall chemical quality of Little Stony Creek. However, during the low flows of summer and fall, their influence causes an increase in the mineral content of the creek.

As the waters in the stream discharge from the mountain range, they flow across the older of the Great Valley sequence rocks before they enter or cross the alluvial plain and enter the reservoir.

The sedimentary deposits of the older Great Valley sequence rocks are mostly shales which are so fine-grained and compact they do not provide the minerals as would a coarse-grained sandstone. Also, they have been exposed to leaching for such a long period of time that most of their available soluble minerals have been dissolved. As a consequence, there is little influence on the chemical concentrations in the waters from this formation.

A number of additional samples were collected on Little Stony Creek during periods of high runoff and analyzed for nutrient concentrations. The results of these analyses are included in Table 4, "Surface Water Nutrient Concentrations". The analyses show the nitrates generally occur in highest concentrations at the start of the runoff season and decrease, approaching zero as the season progresses and the flow diminishes. The results of organic nitrogen analyses were the same and probably reflected the amount of organic debris contained in the original runoff from the watershed. Ammonia was never detected.

Ortho-phosphate concentrations, though low, had their highest values in a pattern that paralleled the nitrate and organic nitrogen. The total phosphorus, however, had its highest values occurring when there were severe storms, heavy runoff, and high turbidity values (see Table 4). Chemical analytical procedures reflected this by detecting the phosphates bound to the particles causing turbidity as well as the phosphorus contained in the organic debris. A more thorough discussion on nutrient inputs from the watershed is included in the limnology section.

TABLE 4

SURFACE WATER NUTRIENT CONCENTRATIONS

Stream	Date	Turb.	NO_3 N	NH_3 N	Organ. N	Ortho P	Total P
Little Stony Cr.	11-28-70	64	0.10	0.00	0.4	0.04	0.17
	12- 4-70	260	0.05	0.00	0.5	0.03	0.40
	12-16-70	30	0.01	0.00	0.1	0.01	0.03
	12-21-70	16	0.02	0.00	0.1	0.01	0.02
	1-15-71	38	0.00	0.00	0.1	-	0.02
	1-16-71	325	0.06	0.00	0.6	0.03	0.24
Hyphus Creek	11-28-70	24	0.43	0.01	0.4	0.03	0.06
	12- 4-70	28	0.28	0.00	0.2	0.02	0.06
	12-16-70	18	0.10	0.00	0.2	0.01	0.02
	1-16-71	120	0.14	0.00	0.4	0.02	0.09
Indian Creek	11-28-70	130	0.42	0.00	0.6	0.06	0.13
	12- 4-70	70	0.29	0.00	0.4	0.03	0.12
	12-16-70	42	0.28	0.00	0.3	0.04	0.06
	12-21-70	35	0.28	0.00	0.3	0.04	0.06
	1-16-71	185	0.21	0.00	0.6	0.06	0.18
Squaw Creek	11-28-70	148	1.4	0.02	0.7	0.07	0.17
	12- 4-70	82	0.46	0.00	0.4	0.04	0.12
	12-21-70	65	0.20	0.00	0.5	0.02	0.19
	1-16-71	225	0.73	0.00	0.8	0.06	0.17
Rainbow Canal	10-22-70	12	0.62	0.00	0.2	0.07	0.10
	11-28-70	160	0.30	0.00	0.5	0.02	0.27
	12- 4-70	30	0.20	0.00	0.4	0.05	0.09
	12- 9-70	90	0.01	0.00	0.4	0.01	0.48
	12-11-70		0.07	0.00	0.2	0.01	0.07
	12-16-70	81	0.06	0.00	0.2	0.00	0.12
	1-16-71	110	0.17	0.00	0.5	0.07	0.11

Calculated on a weighted average, Little Stony Creek contributed 24,950 pounds of nitrogen and 11,550 pounds of phosphorus to East Park Reservoir from October 1970 to April 2971.

Hyphus Creek

Hyphus Creek is located just north of the Little Stony Creek watershed and drains the same geologic belts as Little Stony Creek, though in different proportions.

The water from this drainage is magnesium bicarbonate in character. Its higher magnesium concentration indicates a greater influence from

the serpentine formation. Other than having high hardness values, the water is generally good for all beneficial uses.

Comparison of the nutrient values shows that nitrate values were higher than in Little Stony Creek, while the organic nitrogen and ortho-phosphate were about the same. The total phosphate values also were less, but so were the turbidity values.

Nutrient contribution to East Park Reservoir from Hyphus Creek, based on a weighted average calculation, was 3,300 pounds of nitrogen and 275 pounds of phosphorus.

Indian Creek

Indian Creek has two major tributaries, one draining the western portion of the drainage area and one draining the eastern portion. The one draining the western area has its headwaters in the lower elevations of the Coastal Range in ultrabasic rock that has been serpentinized. It then flows through the older western portion of the Great Valley sequence before entering the alluvial plain in Indian Valley.

The eastern tributary, Little Indian Creek, has its headwaters in the valley foothills which comprise the eastern boundary of the East Park Reservoir drainage. Waters draining the western portion of the watershed have higher electrical conductivity to flow ratios than do those waters draining the eastern portion. This is because of the influence of the waters leaching the serpentine formation.

Specific conductance values of the waters in the Indian Creek drainage appear to be higher overall than those in Little Stony Creek, which would indicate that the Indian Creek drainage is contributing more of a load of dissolved minerals per unit volume of water. Electrical conductivity to flow ratios, however, show this not to be true. Waters draining from the Greater Valley sequence formation have relatively lower dissolved minerals as most of their soluble minerals have been removed prior to their deposition.

An analysis of a sample of water collected from Indian Creek at the Ladoga bridge on March 24, 1971, shows the water is a magnesium bicarbonate water. The flow from Stites Spring apparently has little effect on Indian Creek waters as the sulfates increase only slightly.

Chemical quality of water from the Indian Creek drainage is generally good for most beneficial uses except that treatment for hardness would be required for some uses.

The nitrate values in waters analyzed from Indian Creek are fairly high, varying from 0.21 mg/l to 0.42 mg/l. They follow the same concentration pattern as the rest of the East Park watershed by being high at the start of the runoff season and diminishing as the season progresses. The organic nitrogen values are also relatively high, with

no analyses showing concentrations below 0.3 mg/l. The ortho-phosphate and total phosphate values are relatively high with ortho-phosphate accounting for an unusually large proportion of the phosphate present. This stream accounted for 15,400 pounds of nitrogen and 2,350 pounds of phosphorus.

Squaw Creek

Analyses of samples collected during March 1971 show that Squaw Creek had the poorest quality of water of any of the tributaries to East Park Reservoir. The analyses show the water having sulfate concentrations of 333 parts per million with an electrical conductivity value of 1,250 micromhos.

Measurements of electrical conductivity made throughout the year from October 1970 through March 1971 show the values varying seasonally from a low of 250 mincromhos at high flow to 1,320 micromhos during the low flows. Electrical conductivity to flow ratios show the waters contain less dissolved minerals per volume of flow than do the waters from Little Stony Creek.

The overall chemical classification is that Squaw Creek water is an extremely hard water relatively high in sulfate but still suitable for most beneficial purposes, with treatment for hardness removal being required in some instances.

Squaw Creek waters also have the highest nutrient concentration of any streams entering the reservoir. Nitrate values varied from 1.40 mg/l in the initial flows down to 0.20 mg/l in the latter part of the runoff season with an increase to 0.73 mg/l during a storm on January 16, 1971.

Organic nitrogen varied from 0.7 mg/l down to 0.4 mg/l.

Though soluble ortho-phosphate values were comparatively high, the total phosphorus values were even higher and fairly uniform in concentration, varying only from a low value of 0.12 mg/l to a high of 0.19 mg/l.

Even with these high values, because of the low outflow Squaw Creek contributed only 3,000 pounds of total nitrogen and 400 pounds of total phosphorus to the reservoir.

East Park Feeder Canal

Diversion to East Park Reservoir from Stony Creek via the East Park Feeder Canal began in October 1970. The quality of water from this diversion reflects the quality of water in Stony Creek. As the diversion dam is located above the serpentine belt, the water coming from the drainage has been exposed only to the Franciscan Formation. However, as the canal traverses the side hill, it intercepts drainage which comes from the serpentine area.

The water is of excellent quality and suitable for most beneficial uses. An analysis of a sample collected in March 1971 shows the water to be calcium bicarbonate, low in dissolved minerals. Conductivity values varied from 125 to 530 micromhos, with the higher values generally occurring at the first of the runoff season. Nitrate concentrations in these waters show the same seasonal variation with the initial inflows having the highest values and reducing in concentration as the runoff season progresses. Organic nitrogen values are about the same as in Little Stony Creek, as are the ortho-phosphate values. Total phosphorus values, however, have an overall slightly higher value.

Sixteen percent of the total inflow to East Park Reservoir came from Stony Creek via the East Park Feeder Canal. This inflow accounted for 15,350 pounds of nitrogen and 3,150 pounds of phosphorus input.

Contiguous Area

No analyses were made on the waters flowing from the area contiguous to the reservoir; however, because of short contact time with the geologic formation before runoff enters the reservoir, this water should be low in dissolved minerals. Also, a major portion of the contiguous area is composed of the older sedimentary deposits of the Great Valley sequence formation and most of the soluble chemicals have already been leached from the soils.

Nutrient input was estimated based on judgment and knowledge of the precipitation contributions.

It is estimated that the contiguous area contributed approximately 4,950 pounds of nitrogen and 575 pounds of phosphorus to East Park Reservoir.

Precipitation

Precipitation samples were collected at the dam tender's residence near the dam by using a funnel that had been prewashed with a diluted hydro-chloric acid and rinsed with distilled water. Samples were collected daily during storm periods and analyzed for nutrient content. Analysis of the data shows the nutrient concentrations following the same pattern noted elsewhere; that is, that nutrient concentrations in precipitation are relatively high at the beginning of the storm, but dwindle to almost nothing as the storm progresses. This occurs for every storm except the beginning values do not recover to the previous storm high level unless there is a considerable time interval between storms.

Nitrogen in the form of nitrates and organic nitrogen is the primary nutrient contributed by precipitation. Very small concentrations of phosphorus are present with soluble phosphate being present in quantities of 0.01 ppm or less. Total nitrogen input from precipitation directly on the reservoir was estimated at 750 pounds and phosphorus as 50 pounds.

LIMNOLOGY

Limnology is that branch of science that deals with the study of fresh waters, specifically lakes or reservoirs. These studies include the physical, chemical, and biological conditions within the body of water. The following characteristics of East Park Reservoir were observed and measured: the temperature of the water column, the amount of dissolved oxygen present in the water column, transparency of the surface water, the turbidity of the water throughout the column, and the specific electrical conductance of the water in the reservoir. The water column is defined as the water existing throughout the entire depth of the reservoir.

Reservoir waters were characterized as to their chemical constituents, including such nutrients as nitrate (NO_3), ammonia (NH_3), organic nitrogen (Org. N.), ortho-phosphate (PO_4), and total phosphorus (total P).

Three stations were established to sample algae populations. The algae samples were identified and the cells were counted and measured to obtain an estimate of the biomass volume.

Station 1 was placed in the Indian Creek arm about 1-1/2 miles north of the Ladoga bridge where the water depth was 7 meters (23 feet) deep when the reservoir was at full capacity.

Station 2 was located in the Indian Creek arm halfway between Station 1 and 3 during the 1968 survey, but the data from this station duplicated the data at Station 3 and so was not used throughout the complete study.

Station 3 was established about 1,000 feet upstream from the face of the dam. Depth of water here was 20 meters (66 feet).

Station 4 in the reservoir was placed in the Little Stony Creek arm about 1 mile upstream from Station 3. Depth of water here was about 7.5 meters (25 feet).

Temperature

Ecologists consider temperature one of the primary controls of life on earth. Each aquatic species becomes adapted to the seasonal variations in the temperature of the water in which it lives. Some organisms can reproduce only under certain temperature conditions.

Temperature affects the growth rate and the longevity of aquatic organisms. Organisms living in cold water may grow slower but larger, whereas high temperatures may lead to short but exhausting rapid growth. Most of the effects of temperature, though, are on an organism's rate of metabolism, which, generally speaking, doubles or triples through each 10-degree centigrade increase in temperature within the range of temperature tolerance.

Temperature not only has a physiological effect on a body of water, but also a physical effect. The physical effects are on density, viscosity, and surface tension.

In general, the temperature cycle in a large body of water is determined by its latitude, altitude, and climate. Studies of existing reservoirs in Northern California show the water temperature cycles following a definite seasonal pattern. The temperature of the water in a reservoir is fairly uniform from top to bottom from early fall to late spring. This homothermous condition during the winter season makes it possible for winds acting on the surface of the water to set up currents which thoroughly mix the waters in the reservoir. This mixing recirculates and disperses the nutrients and resuspends low density sediments that have settled into the lower waters during the quiescent periods.

As the warm summer season approaches, the surface waters are warmed, making them less dense and allowing them to float on the colder, denser lower waters. The warm upper layer is called the epilimnion, and the lower stratum, the hypolimnion. When the warm upper layer of water becomes deep enough, temperature stratification in the water column takes place. This thermally induced stratification is so strong that it forms a barrier that prevents any further mixing of the warm epilimmetic layer with the colder hypolimmetic layer.

This stratification has a profound effect on a reservoir. For instance, the algae that are living in the epilimnion can sink into the lower stratum of the reservoir when they die and the nutrients in their cells are thus removed from circulation and further use in the epilmnion; in effect, the epilimnion tends to be stripped of nutrients and there is less subsequent algae growth.

To determine the temperature cycle in East Park Reservoir, temperature profiles were usually made at all three of the stations starting in February 1970 and concluding in March 1971, although Station 3 was the only one where temperature was measured on every survey. These data are included in Table 5, "Limnology Data on East Park Reservoir"

The data show that the temperature follows the same general cycle as the seasons with the lowest temperature at all three stations occurring during February when measurements of 7.6°C, (46°F.) on the surface and 5.8°C. (42°F) on the bottom were recorded.

As solar radiation increased and the warmer seasons approached, the lake began warming until it reached its maximum temperature. At Stations 1 and 4 this occurred in the latter part of July when temperatures on the surface reached 29°C. (84°F.) and 27°C. (81°F.) on the bottom. At Station 3 the highest temperature measured 29°C. (84°F.) on the surface and 18°C. (64°F) at the bottom, and occurred during the first week of August. There is no evidence that thermal stratification occurred at Stations 1 and 4, though the data at Station 3 shows the beginning of thermal stratification by the middle of April.

Using the temperature data, an estimation was made of the area of the reservoir that was covered by epilimnion and the hypolimnion at the time of each survey. These calculations show that at no time was more than 60 percent of the area of the reservoir covered by stratified waters. This data and the volume of each stratum are presented in Table 6, "Areas and Volumes of Epilimnetic and Hypolimnetic Water in East Park Reservoir - 1970". In the spring when waters are first withdrawn from the reservoir, they are released through three outlets with the highest being 43 feet below the surface at an elevation of 1,156 feet. There is only 5,000 acre-feet of water below this elevation in the reservoir. With the outlets in these locations, only hypolimmetic water is removed.

By the first of September, withdrawals have reduced the water level to the point where thermal stratification can no longer be maintained and the lake then becomes completely mixed once again.

Dissolved Oxygen

The reduction of circulation in a body of water can cause other reactions in the water column. One of these is oxygen depletion in the hypolimnion. Though not a direct cause of temperature, the depletion results from temperature-caused conditions.

Dissolved oxygen in water is necessary for the support of higher forms of aquatic life. There is generally not too much concern about a surplus of dissolved oxygen, but only with a deficiency.

Though oxygen normally comprises approximately 20 percent of the atmosphere, the transfer of oxygen from air to water is extremely inefficient. Transfer of oxygen takes place in two primary ways: through wave action and through the photosynthetic process in algae production. The movement or distribution of oxygen throughout the water mass is not entirely dependent on molecular diffusion but involves water movement. Water movement throughout the water column is prevented as thermal stratification takes place.

The hypolimnetic waters containing oxygen that was placed in the water during the time of free circulation cannot be replenished as it is depleted or used up by living or decaying materials that settle into the reservoir. Higher organisms dependent on oxygen to sustain life will not move into these waters. Thus, when these oxygen depletion conditions occur, fish are not able to use the entire body of water and are confined to those areas where there is oxygen available, the epilimnetic waters.

Associated with oxygen depletion is a sulfate reduction process which produces hydrogen sulfide gas. When sulfate reduction occurs, carbon dioxide concentrations are increased and the pH of the water is lowered, making the water slightly acidic. These reduced conditions permit many of the chemicals that have been oxidized and precipitated to be brought back into solution.

TABLE 6

AREAS AND VOLUMES OF EPILIMNETIC AND HYPOLIMNETIC WATER
IN EAST PARK RESERVOIR - 1970

Date	Total Area Acres	Total Volume A.F.	Area in Epilim. Acres	% of Area	Vol. of Epilim. A.F.	Area of Hypolim. Acres	% of Area	Vol. of Hypolim. A.F.	Vol. Released Between Surveys
5-1-70	1,780	47,990	1,780	100		-0-	-0-		
5-13-70	1,680	43,540	740	44	26,000	940	56	17,540	4,450
5-28-70	1,530	37,440	750	49	24,440	780	51	13,000	6,100
6-17-70	1,380	32,250	660	48	20,750	720	52	11,500	5,190
7-2-70	1,260	27,650	700	56	19,650	560	44	8,000	4,600
7-23-70	1,040	20,200	480	46	12,200	560	54	8,000	7,450
8-3-70	930	17,050	370	40	9,050	560	60	8,000	3,150
8-19-70	680	10,650	280	41	5,650	400	59	5,000	6,400
9-2-70	400	5,120	400	100	5,120	-0-	-0-	-0-	5,530
9-23-70	220	2,450	220	100	2,450	-0-	-0-	-0-	2,670

The dissolved oxygen concentrations at Stations 1 and 4 during 1970 show that dissolved oxygen is always present throughout the water column. This is expected as the waters in these areas do not thermally stratify.

At Station 3, the only station where thermal stratification was observed, the dissolved oxygen concentrations became depleted in the hypolimnetic waters. This oxygen depletion began when the first stratification took place about the first of April. The first measurements of zero dissolved oxygen concentrations (anaerobic conditions) occurred about the middle of July. This depletion continued until by the middle of August there was no dissolved oxygen in the waters below 5 meters. Not until the reservoir was destratified in September did oxygen again become available to the lower waters.

Water Clarity

The transparency of a body of water has a profound effect upon the aquatic life. The clearer the body of water, the deeper light can penetrate and the larger the volume of water in which primary productivity and photosynthesis can take place.

When bodies of water become turbid, there is less penetration of light, less productivity of phytoplankton, less fish production, and less recreation use.

Turbidity can also modify the temperature structure of lakes by absorbing most of the solar energy near the surface. As a result, the bottom temperatures are lower. The turbidity of water is due to suspended clay, silt, finely divided organic matter, microscopic organisms, and similar substances. The measure of turbidity present in water is actually a measure of the water's clarity. The higher the turbidity values, the lower the clarity.

The clarity of the water in East Park Reservoir was determined by measuring the light scattering properties of suspended particles. This was done by measuring the amount of light reflected at right angles from a beam of light passing through the sample and comparing that to the amount reflected from a beam of light passing through a perfectly clear solution. The amount of reflectence is calibrated and reported in Jackson Turbidity Units (JTU). In this study, a Hach Laboratory Turbidimeter, Model 1860, was used to make the turbidity determinations.

Another measure of the clarity or transparency of water concerns the depth at which an object can be seen by an observer. In this case a white and black disk about 8 inches in diameter (Secchi disk) is lowered with the disk horizontal in the water until it disappears and then raised until it reappears. The two depths at which this occurs are averaged and reported as the Secchi disk transparency. This determination gives some measure of the overall light penetration. The values can be effected by turbidity, color, and absorbency of the water.

As was expected, the shallowest depth at which a Secchi disk could be observed occurred in the winter months during periods of highly turbid inflowing water. Secchi depths of 0.15 meter (6 inches) were common at all stations during this time. JTU's at that time were about 150.

As the inflow decreased and the reservoir became more quiescent, the suspended particles started settling out and the Secchi disk could be observed deeper. The maximum depth observed occurred on May 13 when a Secchi depth of 3.9 meters (12 feet, 9 inches) was noted. JTU's were 2.5. As the water becomes clearer from the inorganic turbidity settling out, it begins to lose its clarity again because of increased growth of aquatic organisms. About three weeks after observing the maximum clarity, Secchi disk measurements are reduced to approximately 1.5 meters (5 feet). There is no drastic change in the turbidity values at this time as the JTU's increased only from 2.5 to about 5. The clarity then continues to decrease until the inflow begins again.

Electrical Conductivity

As discussed earlier, the electrical conductivity of a sample of water is a measure of the dissolved chemicals present. Though included in the physical parameters of a reservoir, conductivity is really an indication of the chemical quality.

Measurements of the conductance of the water in East Park Reservoir show the cycle of the lowest conductance values occurring during the time of highest inflow and increasing in value as the inflow recedes and concentration by evaporation takes place. The highest values occur just prior to inflow of runoff from the winter storms.

The lowest values, 180 micromhos, were measured at Stations 1 and 4 in December. At the same time, Station 3 had slightly higher conductance values of 210 micromhos, probably because the waters in the reservoir had not thoroughly mixed. From December on, the conductance values increased throughout the reservoir. Station 3 conductance equalized with the other station values by February, indicating that the reservoir had then become mixed. Over 400 micromhos, the highest values measured, were recorded in the latter part of September, when there was only 2,400 acre-feet of water remaining in the reservoir. However, the conductance undoubtedly became slightly higher as inflow did not begin until December and no measurements were made from September to December.

Nutrients

The importance of nutrients in surface waters has been discussed previously. When surface waters are impounded, nutrients are of prime importance because of their effect on the biological conditions within the reservoir.

There are many sources of the nutrients in surface waters. They are contributed by natural runoff, agricultural drainage, ground

water inflow, domestic waste discharges, atmospheric sources, reclycling from lake sediments, nitrogen fixation by bacteria or algae, and other sources.

Natural runoff from a watershed is generally the prime source of nutrients to most reservoirs. They are present in the inflowing waters in inorganic forms that have been leached from the soils or geologic formations, or in organic forms such as leaves, grass, or animal wastes. It appears that nutrients contained in the natural inflow are also the prime supply for East Park Reservoir.

Agricultural drainage can be the source of large quantities of nutrients to surface waters. However, there is little if any drainage water in the East Park drainage as there is limited irrigation of crops.

Though some fertilizers are applied to pasture land within the watershed, almost all of them are tied up in the soil structure, lost to the atmosphere, or utilized in plant growth. Misapplication of large amounts of fertilizers could cause problems in that their nutrients could be transported to a water course; however, profitable farming and ranching demand proper management of soil, water, and fertilizer, so that applications of surplus amounts will not occur.

Wastes from farm or grazing animals could become a source of nutrients when large numbers of the animals are concentrated in small areas such as in dairies or feed lots. However, even this source can be controlled if proper facilities are provided to treat the voluminous amount of wastes that are generated.

There are no dairies or feed lots located in the East Park Reservoir drainage. The only concentration of animals are the cattle that are brought in to graze on the watershed.

Each year livestock is brought into the area to grow and fatten and then removed for slaughter. No food is imported to feed the cattle and they eat only what is already within the watershed. A part of the nutrients in the feed are utilized by conversion to body protein. Though the cattle might feed high on the watershed and move down near the water's edge to dispose of their body wastes (which would only increase the rate of recycling of those particular nutrients), the primary effect of cattle on the watershed is to remove nutrients rather than increase the overall load. Agricultural drainage then, is considered to be only a minor source of nutrients to East Park Reservoir, if it is a source at all.

Domestic waste can also be a prime source of nutrients. Various studies have shown that over a one-year period, a person is responsible for contributing 1 to 2 pounds of phosphorus and 5 to 7 pounds of nitrogen to domestic waste.

Present practice in populated areas is to construct a sewage collection system that brings these domestic wastes into a central location

where they can be treated and disposed of with a minimum of problems. A properly operated treatment plant can reduce or remove a major portion of the nutrients present. However, it is the usual practice to discharge this treated sewage plant effluent to water courses, and even small amounts of nutrients can cause problems.

Disposal of domestic wastes to septic tanks, together with underground leaching lines, is common wherever sewer systems are not available. The nitrogen and phosphorus compounds in the effluent then become potential ground water ingredients, and as such, also potential surface water ingredients.

A septic tank generally consists of a concrete tank with a baffled inlet and outlet. As the wastes enter the tank, the heavy solids begin to settle to the bottom and the lighter materials, such as grease and oil, float to the top. Apparently very little of the organic material is completely decomposed in the septic tank, but is discharged to the leach lines along with the soluble chemicals that have been liquified. These suspended solids and water soluble materials then migrate out of the leach lines to the soil adsorption system where a combination of physical, chemical, and biological reactions stabilize the effluent. The success of this method of sewage disposal depends more on providing adequate soil leaching capacity than upon any other single factor.

In the form of nutrients, the average septic tank effluent contains:

Organic	N	10 mg/l
NO_3	N	0
NH_4	N	25
PO_4	P	6

For the typical family of five, this represents approximately 5 pounds of phosphorus and 27 pounds of nitrogen applied to the soil per year.

Many soils are capable of fixing large quantities of phosphorus, thus making it unavailable as a nutrient. The nechanism of fixation is quite complicated but includes (1) adsorption, (2) replacement reactions which may involve changes in the mineral crystalline structure, and (3) precipitation reactions through which the soluble phosphates react with iron, calcium, or aluminum to form insoluble compounds.

The nitrogen compounds present an entirely different problem. Two main factors affect the movement of nitrogen compounds in soils. These are (1) adsorption and ion exchange by soils and (2) the action of nitrifying and denitrifying bacteria.

Most soils have a net negative charge which means that they have the capacity to attract and hold positively-charged ions. Most of

the nitrogen in septic tank effluent is in the form of ammonium ion (NH_4+) which is a positive-charged ion. The combination of the negative soil and positive ion of ammonium lead to the ammonium being fixed to the soil and not going into solution.

The nitrifying bacteria act in opposition to the adsorption process. These organisms have simple food requirements consisting of ammonia nitrogen, carbon dioxide, and oxygen, and their end product is nitrate nitrogen (NO_3). The NO_3 ion is negatively charged and is not adsorbed to any great extent by the soil. It is very soluble in percolating water and can move with the ground water flow.

Under anaerobic (no oxygen) conditions, some bacteria can use nitrates (NO_3) and organic carbon compounds as food. The end product of this reaction is nitrogen gaseous forms: mainly nitrogen, with some nitrous oxide, and nitric oxide. Nitrates can be removed from percolating waters by this process.

If the septic tank effluent could be kept anaerobic, the conversion of NH_4+ to NO_3^- could be stopped and the nitrogen stored on the soil. However, when the anaerobic effluent moves into the soil adsorption system and becomes anaerobic, ferrous sulfide is often produced which clogs the soil and causes the leaching field to fail. If the soil is allowed to dry out by not being used for some time, the ferrous sulfide is oxidized and the system can be returned to use. This also means that any NH_4+ present can be oxidized to NO_3^-.

In summary, phosphorus in septic tank effluents that are applied to soils do not appear to present a serious problem to ground or surface waters if the leach lines are located in good soils. However, it appears that if the septic tank effluent is not kept anaerobic, the nitrogen compounds are rapidly oxidized to nitrate nitrogen which can move in the ground water without being tied up and could eventually be sources of nutrients to surface waters.

In non-sandy soils, septic tanks generally fail in relatively short periods of time due to the plugging of the leach field surrounding the effluent lines. When this occurs, continued use of the system will force water from the leach field to the surface and the nutrients could then be transported overland to nearby surface streams. As there are probably not more than 100 people living on the watershed, and all of their wastes are disposed to septic tank disposal systems, domestic wastes are considered only a minor source of nutrients to East Park Reservoir.

Ground water accreting to the surface waters can contain large concentrations of nitrate nitrogen and other micronutrients. In the East Park drainage, ground waters generally show up as springs. As there are no extensive ground water bearing stratas adjacent to the reservoir, contributions of nutrients to the body of water from this source is believed minor. Ground water accretions are directly to the streams and appear as surface water inflow.

Atmospheric sources in the form of rainfall and dust can contribute substantial amounts of nitrogen to a body of water though phosphorus contributions are generally low. To East Park Reservoir, this source of nitrogen is significant at the start of the rainy season when the volume of the reservoir is low, but becomes less as the storms and inflow progress. The total nitrogen contribution from this source is one to two percent of the total input to the reservoir and thus is relatively minor. Phosphorus input by precipitation is negligible.

Lake sediments are excellent sources of nutrients to the overlying waters. Numerous analyses show sediments often contain thousands of milligrams per kilogram dry weight of phosphorus and nitrogen. If the sediments are mixed with water and contain leachable nutrients, potentially small quantities of sediments could fertilize large quantities of water. Fortunately though, most of the nitrogen and phosphorus present in sediments are in non-leachable forms. Phosphorus can be released from the sediments under both aerobic and anaerobic conditions, though considerably more is leached under anaerobic conditions.

Sediments can also contribute nitrogen to the overlying waters. This occurs mainly through micro-organisms which transform the organic nitrogen present into more soluble forms such as ammonium and nitrate.

The present operation of East Park Reservoir has a tremendous impact on the contribution of nutrients from the sediments.

The highest rate of contributions from sediments occurs when anaerobic conditions are established in the sediments. As pointed out previously, this condition generally does not occur until the middle of July and then only slightly more than one-half of the reservoir's sediments are involved. This means that most of the recycling nutrients coming from the sediments enter only the hypolimnetic waters. As the reservoir is being drawn down at that time, and as the outlets are all located in the hypolimnion, these regenerated nutrients are being removed with the outflow and are not utilized within the reservoir. The only exceptions to this are those nutrients in the hypolimnion at the time that thermal stratification is overcome in the latter part of August. The regenerated nutrients are then mixed throughout the water column and are available for any aquatic growth that can occur at that time of year.

Some nutrients from the sediments are placed back in solution by the wave action on the shores of the reservoir. As the reservoir is drawn down, new sediments continue to be worked and resuspended by the wave action. This action provides a major nutrient supply.

Drawdown of the reservoir begins in May. As the waters recede, sediments in the upper reaches of the reservoir become exposed. This drawdown continues and by mid-September almost all of the sediments in the reservoir are exposed. As the waters recede, the sediments are drained internally and then are as soils. Vegetation in the form of weeds and grasses establish themselves and grow profusely. This vegetation utilizes large amounts of the inorganic nutrients and converts them

to organic nutrients by incorporating them into its cell structure. The vegetation is grazed upon by cattle, deer, and wildfowl, which remove some of these nutrients from the reservoir. However, a major portion of the vegetation remains until the following winter when rising waters inundate it. It then becomes part of the organic material in the reservoir.

Nitrogen can also be lost from these exposed sediments by volatilization. This denitrification is accomplished by microbial conversion of nitrate to nitrogen's gaseous forms.

Because of the pattern of withdrawal of water in storage in East Park Reservoir, and the other factors just discussed, the effect on primary production by nutrients from this source is minimal.

Fixation of atmospheric nitrogen into a form that is usable for nutrients by aquatic organisms is a phenomenan that is restricted to a few bacteria and a small number of blue-green algae species. These organisms can utilize the nitrogen in the dissolved gasses in the water by converting it to ammonia and organic nitrogen. The rate of fixation depends on a number of conditions and varies for each body of water.

No studies were made during this investigation to determine the amount of nitrogen contributed to the system by fixation of gaseous nitrogen; however, there can be no doubt that some fixation takes place. This is concluded because of the presence and continued productivity of known nitrogen fixing blue-green algae at a time when nitrogen depletion had occurred throughout the water column.

The approximate amount of nitrogen contributed by fixation can be deduced, however, by accounting for the tonnage of nitrogen present in the reservoir during each of the surveys. This is described further in the following section dealing with the nutrient balance of the reservoir.

Miscellaneous sources of nutrients to the drainage would be wastes from wild ducks, geese, and other organisms. Their contribution is probably insignificant in that they feed primarily in the water or on the shore, ingesting nutrients already within the basin, and probably increase the rate of recycling rather than the amount. If they are migratory fowl coming to the reservoir only to feed, they probably remove more nutrients from the basin than they import.

Nutrient Balance

Before any type of control of a body of water can be undertaken, it is necessary to know the factors affecting that body.

One of these factors that needs understanding is the nutrient balance, which can be determined by establishing where the nutrients come from, what happens to them after they enter the reservoir, and what is their final disposition. It would be ideal in obtaining answers to these questions to study a reservoir through an annual cycle, starting in

the fall when the storage is lowest and continuing through the winter and spring inflow period and on through summer when biological productivity in the reservoir is at its maximum until the lowest point is reached again in the fall.

The scheduling of this study did not permit this exact sequence; however, a balance of the nutrients in the water column was made that started when the reservoir was at its maximum storage capacity in February 1970 and continued until the storage was at its lowest at the end of September. The nutrient input portion then proceeded forward from the first inflows of that winter until the reservoir was filled to capacity in the spring of 1971 and almost all inflow had ceased. From this information, one can analyze to some degree what happens to the nutrients after they enter the reservoir and what their final disposition is, and present a general picture of the nutrient balance of East Park Reservoir.

The nutrient balance was derived from data collected during 14 surveys made at two-week intervals. Data collected included nitrogen and phosphorus concentrations present in the water column and in the releases from the reservoir.

Tables 7 and 8 give the pounds of nitrogen and phosphorus in the water column at the time each survey was made, the amount removed in the releases, and the total pounds lost or gained between surveys.

These data show that there is a total reduction of 64,000 pounds of nitrogen in the reservoir waters between the first and last surveys, though the outflow quantities accounted for only 47,300 pounds.

This would indicate that 15,700 pounds of nitrogen is tied up in the sediments, or is lost to the atmosphere by the denitrification.

For the same period, the phosphate reduction was 23,300 pounds, with only 10,350 being accounted for in the outflow or releases.

Approximately 13,000 pounds of phosphorus was removed from the water column and, in the case of phosphorus, was probably deposited in the bottom sediments.

The possibility of nitrogen fixation is shown in the data presented in the nitrogen balance discussion. From the survey made on May 13 to the survey of July 23, a total of 7,800 pounds of nitrogen was removed from the reservoir by releases. There was no detectable nitrate or ammonium in the water column and recharge from surface inflow was negligible, yet there was an increase of 8,600 pounds of nitrogen, all in the organic nitrogen phase. As the reservoir was stratified during this period, it is not believed that regeneration from the bottom sediments can account for the total input of over 16,000 pounds of nitrogen to the total water column. Biological samples collected prior to May 23 contained no blue-green algae. From that date forward the blue-green algae became well established and produced large volumes of biomass in waters depleted

TABLE 7

NITROGEN BALANCE - EAST PARK RESERVOIR
February 6, 1970 to September 23, 1970

Time Period	Total N in Water Column at Beginning in Lbs.	Total N Removed by Spills-Releases in Lbs.	1-2	Total N in Water Column at End of Time Period in Lbs.	Total N Loss or Gain in Water Column in Lbs.
2/6 to 3/17	66,800	20,700	46,100	37,100	- 9,000
3/17 to 4/1	37,100	700	36,400	29,300	- 7,800
4/1 to 4/13	29,300	300	29,000	36,200	+ 7,200
4/13 to 5/1	36,200	2,300	33,900	28,600	- 5,300
5/1 to 5/13	28,600	2,300	26,300	16,600	- 9,700
5/13 to 5/28	16,600	1,500	15,100	16,200	+ 1,100
5/28 to 6/17	16,200	1,700	14,500	17,500	+ 3,000
6/17 to 7/2	17,500	2,100	15,400	16,400	+ 1,000
7/2 to 7/23	16,400	2,500	13,900	17,400	+ 3,500
7/23 to 8/3	17,400	2,600	14,800	14,100	- 700
8/3 to 8/19	14,100	3,800	10,300	9,800	- 500
8/19 to 9/2	9,800	5,000	4,800	5,000	+ 200
9/2 to 9/23	5,000	2,800	2,200	2,800	+ 600

TABLE 8

PHOSPHORUS BALANCE - EAST PARK RESERVOIR
February 6, 1970 to September 23, 1970

Time Period	Total P in Water Column at Beginning in Lbs.	Total P Removed by Spills-Releases in Lbs.	1-3	Total P in Water Column at End of Time Period in Lbs.	Total N Loss or Gain in Water Column in Lbs.
2/6 to 3/17	23,950	3,550	20,400	4,650	-15,750
3/17 to 4/1	4,650	100	4,550	5,600	+ 1,000
4/1 to 4/13	5,600	0	5,600	3,500	- 2,100
4/13 to 5/1	3,500	150	3,350	2,600	- 750
5/1 to 5/13	2,600	300	2,300	4,750	+ 2,450
5/13 to 5/28	4,750	1,150	3,600	4,050	+ 450
5/28 to 6/17	4,050	400	3,650	1,750	- 1,900
6/17 to 7/2	1,750	300	1,450	2,250	+ 800
7/2 to 7/23	2,250	1,100	1,150	4,100	+ 2,950
7/23 to 8/3	4,100	950	3,150	2,300	- 850
8/3 to 8/19	2,300	800	1,500	2,500	+ 1,000
8/19 to 9/2	2,500	900	1,600	1,050	- 550
9/2 to 9/23	1,050	650	400	650	- 250

The fixation of atmospheric nitrogen by the large numbers of nitrogen fixing blue-green algae is the apparent source of this nitrogen increase.

Nutrient Inputs

The input of nutrients to the reservoir was determined by collecting and analyzing samples from every inflowing stream beginning with the first runoff on November 28, 1970.

As the major inflow of nutrients coincides with the periods of heavy storms and runoff, most of the samples were collected during these periods. The nutrient concentrations were then prorated to the measured daily flow to determine the weighted average contributions. These data show that there was an input to East Park Reservoir of approximately 52,000 pounds of nitrogen and 18,500 pounds of phosphorus from October 1, 1970, to March 23, 1971. The contributions in pounds from each source during this time period is shown in Figures 3 and 4.

Biota

Any study of a body of water requires a knowledge and understanding of the relationship between the water living organisms and their environment.

Organisms respond to the conditions in which they exist by producing an aquatic crop that can best adapt to that particular environment. They may also respond to changes that take place within their environment by a shift in the dominant species or by dramatic changes in the population numbers of a single species or group of species with similar habitat requirements. Overproduction, or too much of any one organism, often results in the development of an aquatic nuisance that can impair or curtail legitimate uses of water. The control of this excessive production is of prime importance for those who would use the waters in a reservoir for human use, whether it be fishing, boating, swimming, or domestic consumption.

Once biological nuisances develop, they are likely to remain a problem until basic causes are reduced or eliminated because controls are often costly, time consuming, and usually only temporary. In other words, the best treatment is prevention. Algae are among the most important types of organisms living in the aquatic environment as they constitute much of the base of the food pyramid on which all higher forms of aquatic life depend.

Algae are commonly found in surface waters that are exposed to sunlight. They are important in waters in ways other than being food organisms, for they have the capacity to modify the water's alkalinity, color, pH, and turbidity.

Algae possess an internal green pigment called chlorophyll, sometimes hidden or masked by other pigments, which enables them in the presence of sunlight to combine water and carbon dioxide to form starch or related substances. This process, called photosynthesis, is common to all green

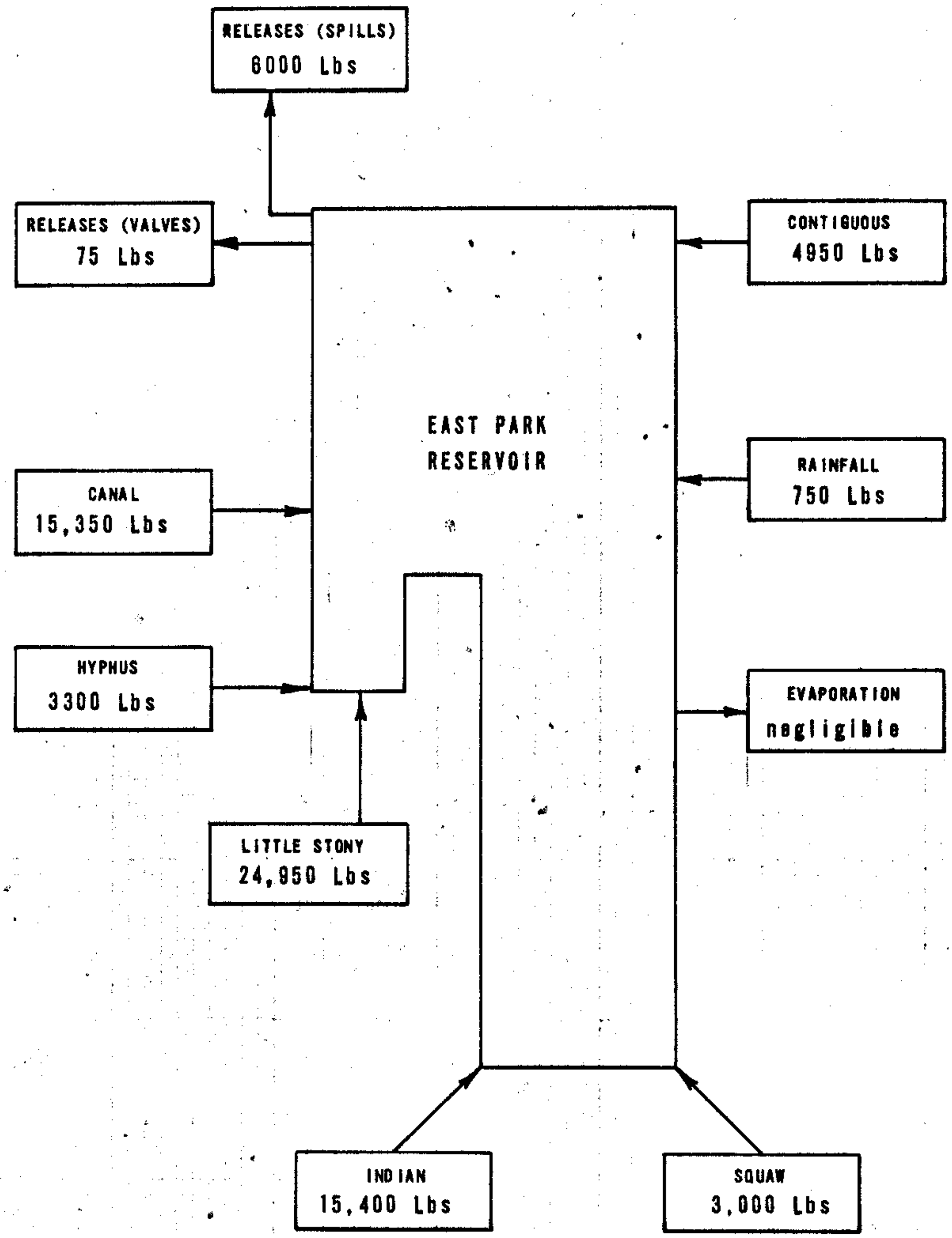


FIGURE 3 INFLOW OF TOTAL NITROGEN IN LBS
October 1, 1970 through March 23, 1971

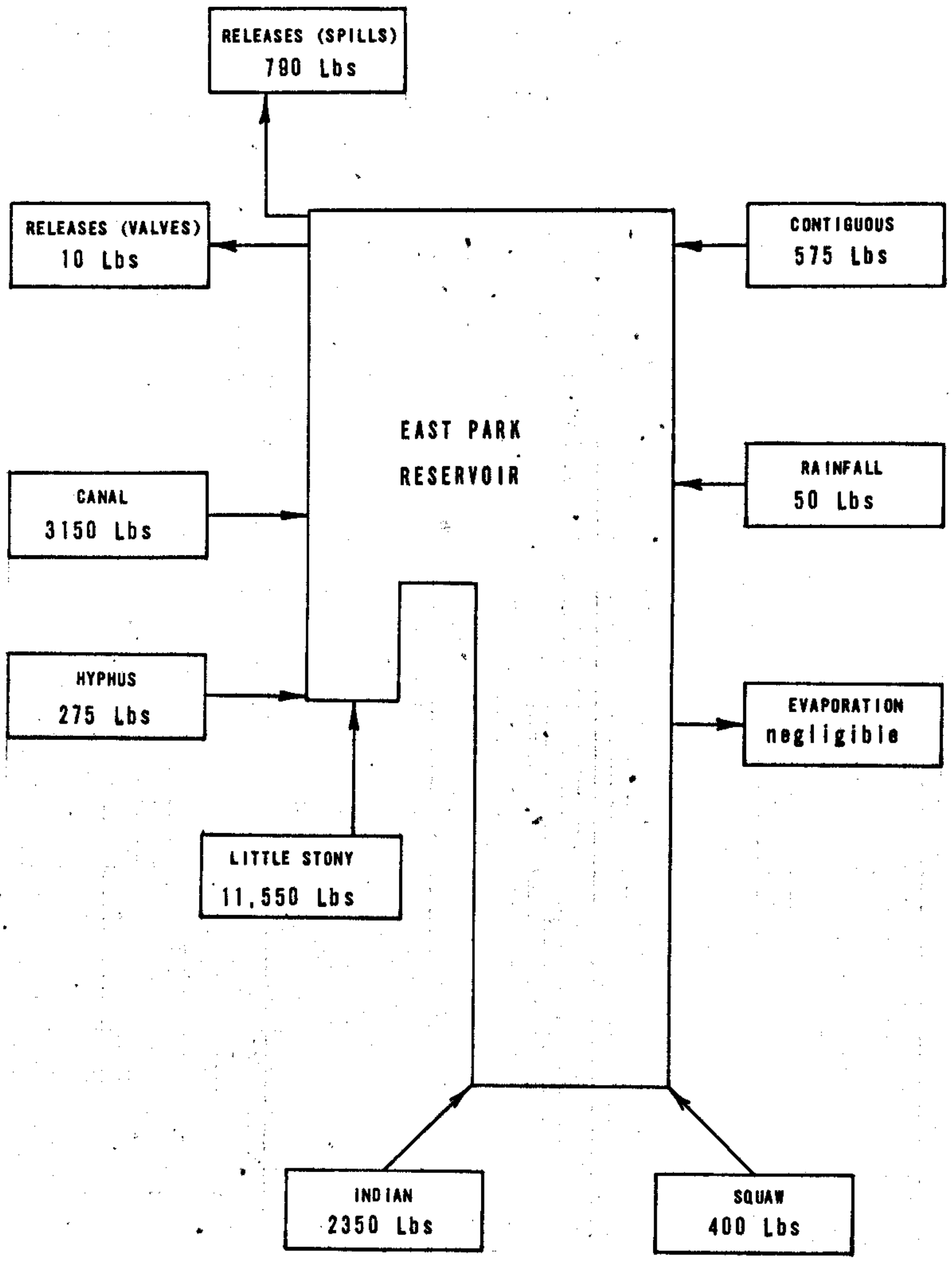


FIGURE 4 INFLOW OF TOTAL PHOSPHORUS IN LBS
October 1, 1970 through March 23, 1971

plants and releases oxygen into the water. On the other hand, respiration, a process carried on by all animals and plants, is the opposite of photosynthesis in that oxygen is adsorbed and carbon dioxide is released.

However, in algae and other green plants, photosynthesis creates oxygen faster than it can be used in the plants' respiration process. This surplus oxygen is released to the water where it becomes available for respirational use by fish on down to the smallest forms of life. Oxygen released in the photosynthetic process by algae is the primary source of daytime renewal of this essential element in most bodies of quiet water.

At the present time, there is no single analytical tool to measure the biomass of a given body of water. It would seem logical to use the total number of organisms present in the standing algae crop as an estimate of the biomass of a lake or reservoir. This would be extremely difficult, however, because water currents and movement cause a diverse horizontal and vertical dispersion of the organisms and a large number of samples would be required.

A better approach would be to measure a few different parameters to determine the general production of biomass in a few select areas in the reservoir which would give a somewhat overall average degree of productivity for the water. This is what was done for this study.

Samples of phytoplankton (the free-floating plant life of a body of water which includes algae) were collected throughout the water column at three stations using a sampling device that was approximately one meter in length. The sampling interval was as shown in the following tabulation:

Sample Depth in Meters	Depth Interval of Sample in Meters
Surface	0 - 1
3	2.5 - 3.5
6	5.5 - 6.5
9	8.5 - 9.5
12	11.5 - 12.5
15	14.5 - 15.5
18	17.5 - 18.5

Additional samples were collected at other stations, but only from the top meter and only for species correlation with the other stations.

Samples were preserved using an iodine solution (Lugols solution) and transported to the laboratory where the phytoplankton in each sample was identified to genus by microscopic examination. Cell counts were made of each genus using a Sedgewick-Rafter cell. In addition, a number of cells were measured for their volumes to estimate the average algal volumes in the water column.

For convenience, the algae were divided into four simplified general groups: the blue-green algae, the green algae, the diatoms, and the pigmented flagellates.

Blue-green algae are the most probable of all the algae that could become prominent in a lake and cause nuisance problems. As the name implies, many of the blue-green algae have a blue-green color. They are generally surrounded by a slimy coating and their form and internal structure is relatively simple. They are primarily floating and dependent on the currents to move about. In calm weather, many of the blue-green algae, which contain air vacuoles, float to the surface and accumulate as scums rather than sinking as other algae do.

Blue-green algae are adaptable and have been observed under a variety of conditions. Their growth has been noted under an ice cover and also in hot water springs. The most favorable conditions for their growth appear to be in water of low mineral concentration and high organic content. Organic pollution almost always assures an over-abundance of blue-green algae. Excessive blue-green algae growth can also occur during periods of moderately high water temperature and light intensity.

There is evidence that although blue-green algae may be ingested by higher forms of aquatic life, they are difficult to digest and do not appear to be a primary source of food. Some species can and do produce toxins that are harmful to higher forms of animals and can act as an inhibitor on the growth of other algae.

Green algae are often free floating and are grass-green to yellow-green in color. Having cell walls that are semi-rigid, smooth or with spines, they are more complicated in internal structure than the blue-greens. They are seldom sources of nuisance blooms as they cannot fix atmospheric nitrogen; thus, they quit reproducing as soon as the soluble nitrogen in the water is exhausted.

They are an essential link in the food chain and their concentrations are heavily grazed upon by higher forms of life such as zooplankton or fish.

Diatoms are distinguished from other algae by one primary feature, the presence of rigid cell walls that are composed of two overlapping halves that fit together. These rigid walls are composed mostly of silica which is sculptured with regularly arranged markings. Their color is from brown to light green. Many have the ability to move about spontaneously and they are an excellent source of food for higher organisms.

The pigmented flagellates have a more complicated form and structure than the other algae. They often possess a red eye spot and have one or more flexible whip-like hairs known as flagella extending from their cells. These flagella are whipped about spontaneously and tend to move the algae through the water, though their direction of movement in general is not controlled, but random. Flagellates vary in color from green to brown.

In the field of ecology, it is generally accepted that an adverse environment will result in a decrease of the number of species, although the total number of organisms of a given species may increase because of reduced competition. Thus, an examination of the diversity of organisms may provide an indication as to the "general health" of the environment.

Algae identified in East Park Reservoir and the time period that they were present are shown in Figures 5 and 6. These figures categorize the algae into the four general groups of blue-green, green, diatoms, and flagellates with each group broken down as to genera. These data show the progression of the different species as environmental conditions within the reservoir change. The overall trend is that the diversity of algae is small in the winter months (seven genera identified in February), increases to a high in the summer (24 genera in July), then gradually decreases as the cooler autumn period begins and storage in the reservoir is depleted.

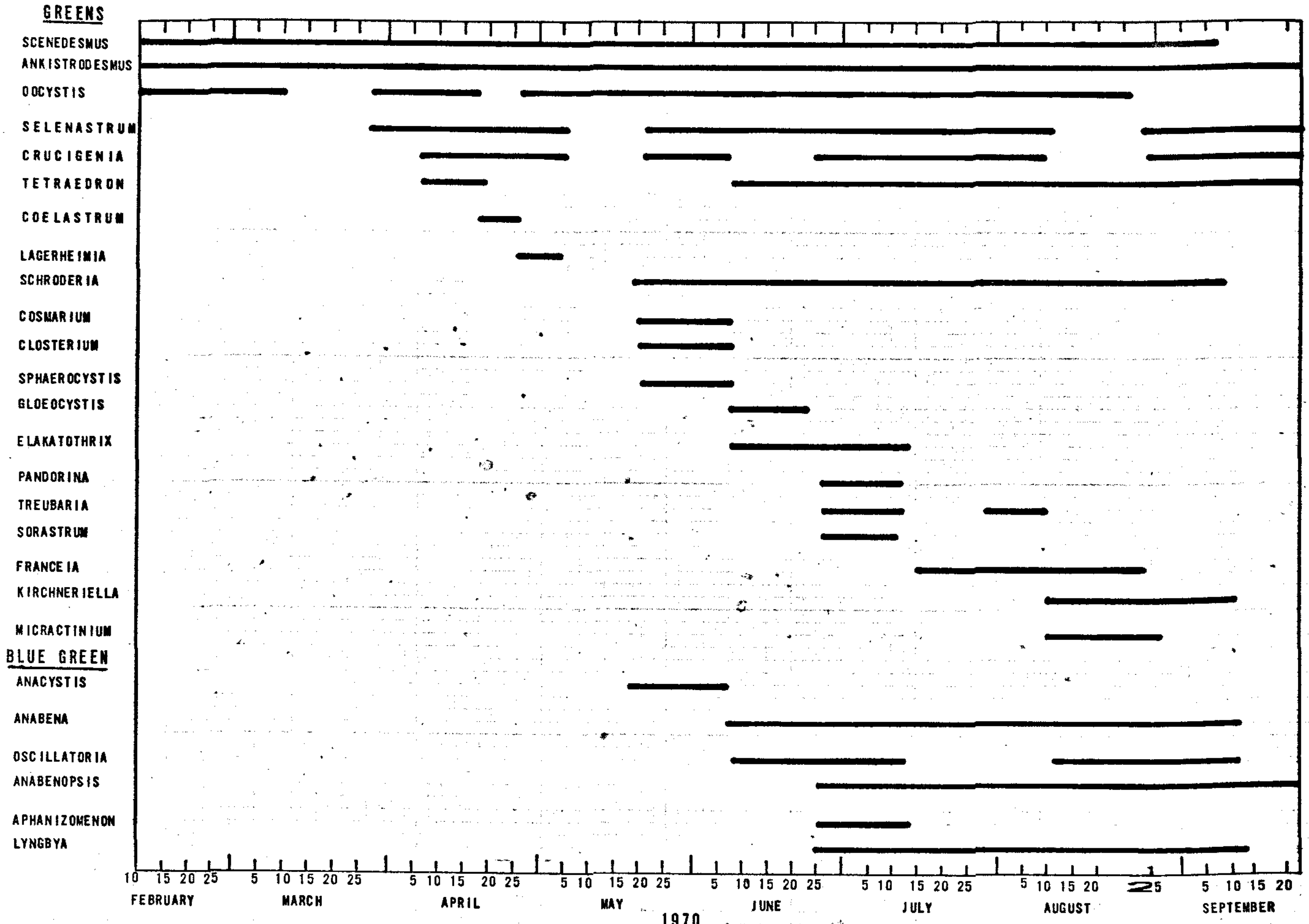
Even with the fierce competition for nutrients by the five genera of blue-green algae present, there are 19 other genera of algae present during the period of high productivity.

However, any good definition of diversity must consider the relative number of each organism as well as the different types. In other words, using just the genera as an indicator can be misleading because the same value is placed on the recognition of one cell of a particular algae as the recognition of one thousand cells of another. For a better interpretation, the cell count and volume must also be considered.

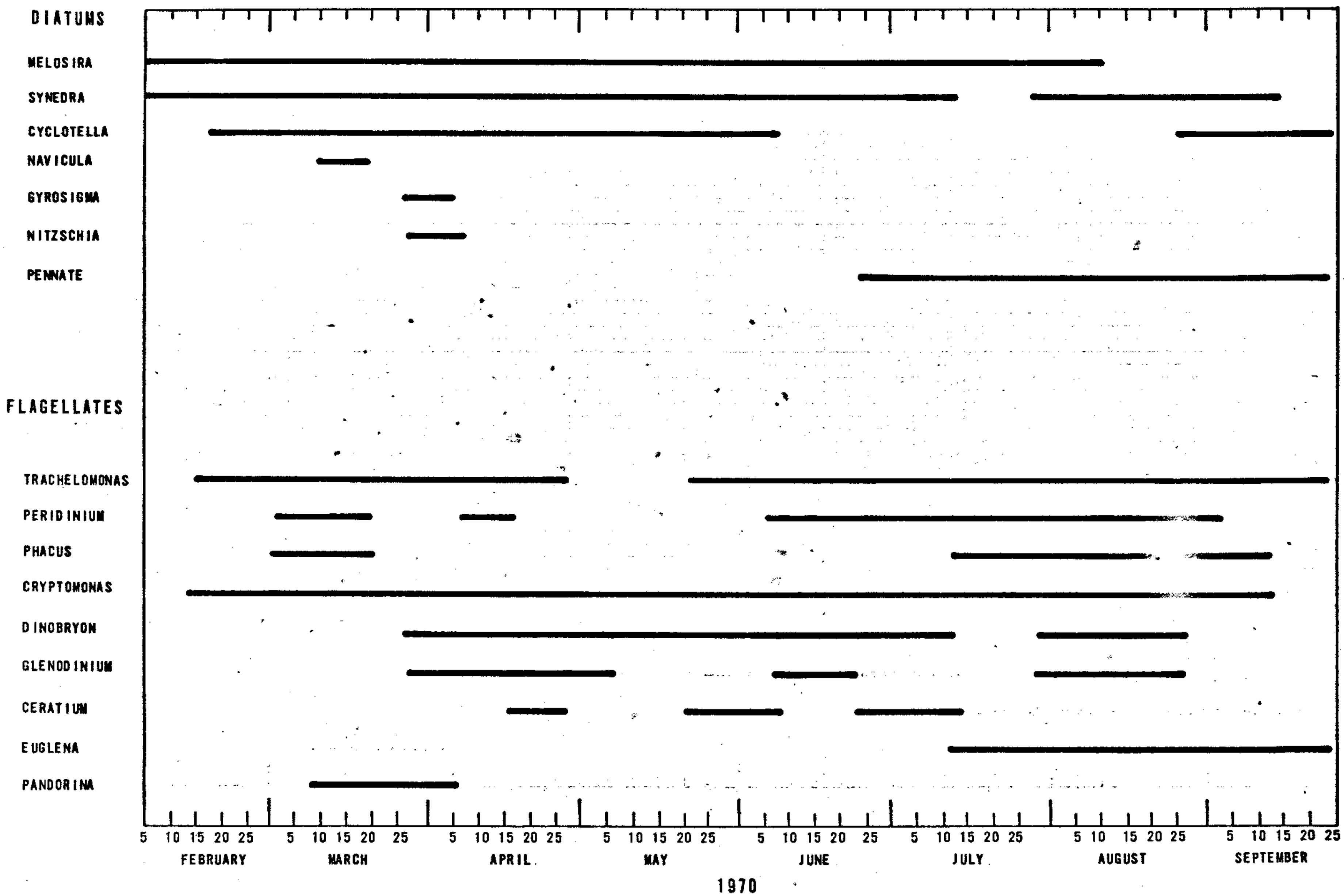
Figure 7 shows the number of cells counted in each group of algae for each survey during the study. These data give a better indication of productivity of certain genera during different environmental conditions. And further, a better understanding can be obtained by comparing the distribution of the volumetric measurements of the algae throughout the water column along with the diversity of genera and cell count. Figure 8 shows the vertical distribution of algae volumes in cubic microns per milliliter (u^3m_l) throughout the water column. These volumes are plotted for each survey that was made at Station 3 during 1970.

The highest total volume measurements of algae occurred at the end of September when the water column contained an average of over 2.2 million u^3m_l. (This is about one percent of the volume measured in the water column in Clear Lake on the same date.)

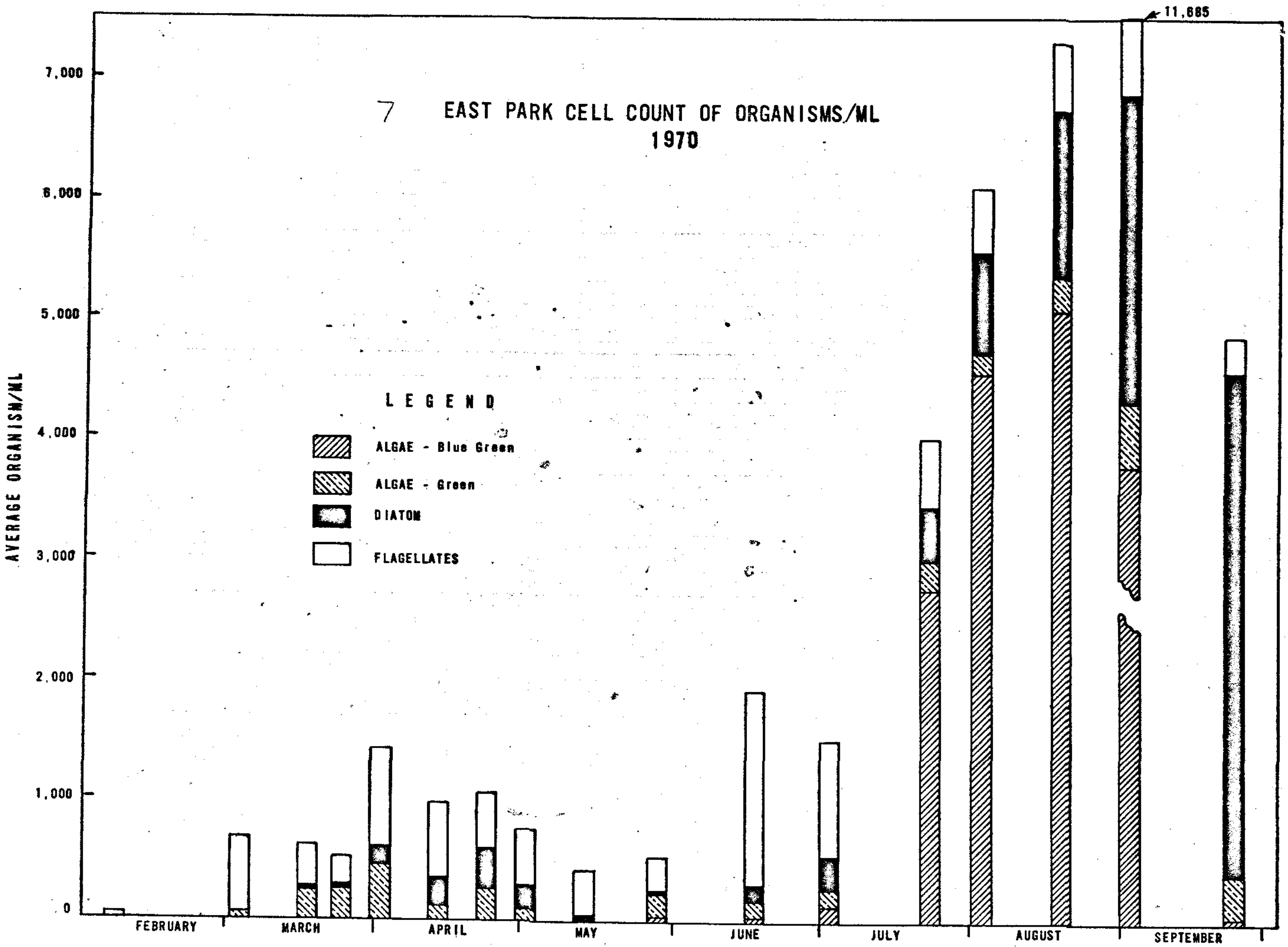
The highest volumes measured in the top meter of water, however, occurred on the 17th day of June. On this date, approximately 5.6 million u^3m_l of algae volume was measured. This is significant for several reasons, the first being that it occurred in the top meter of water where it is most noticeable to a recreationist, the second being that it occurred at a time when the reservoir was at a relatively high level, and the third being that it occurred when there is normally heavy use of the reservoir by recreationists and fishermen.



5 PRESENCE OF GREEN & BLUE GREEN ALGAE IN EAST PARK - 1970



6 PRESENCE OF DIATOMS AND FLAGELLATES IN EAST PARK



7
EAST PARK CELL COUNT OF ORGANISMS/ML
1970
11,685
LEGEND
ALGAE - Blue Green
ALGAE - Green
DIATOM
FLAGELLATES
AVERAGE ORGANISM/ML
7,000
6,000
5,000
4,000
3,000
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FEBRUARY
MARCH
APRIL
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Effects of Development

The amount of biological productivity that can be tolerated in a reservoir generally depends on the use for which the reservoirs water is intended. If the impoundment is used to provide domestic or industrial supplies, the reservoir is usually managed to maintain low levels of biological activity because a large variety of algae impart undesirable taste and odors to water. Water-oriented recreationists that use the reservoir for such activities as swimming and water skiing also desire low levels of biological biomass. On the other hand, operators of reservoirs used primarily for fishing prefer to have high levels of productivity to assure having an ample supply of food organisms for the fish. A farmer using the reservoir waters for irrigation is generally not concerned about the biological activity occurring in the reservoir, but is more concerned about the chemical quality of the water. Thus, multiple uses of a reservoir's water present complicated management conditions.

East Park Reservoir water, though primarily stored for irrigation use, is also used for recreation, mainly fishing, and minimal boating and swimming. Because of the limited water supply in the watershed, any major development requiring large amounts of water will have to obtain its supply from the reservoir.

It is apparent from the data collected during this investigation that East Park Reservoir is, biologically speaking, a productive reservoir. Algae concentrations are sufficient to support a substantial fish population. There could already be a problem existing if the water is to be used for domestic purposes. Eighteen genera of algae that are known taste and odor producers have been identified in the reservoir waters. Some of these types of algae are present throughout the year. Also, the presence of blue-green algae from June on could also present problems in drinking water supplies as the species present are known to contribute toxic elements to surface waters.

The use of East Park Reservoir for water-associated recreation such as boating and water skiing is restricted by the remoteness of the reservoir, the lack of recreational facilities around the reservoir, and the early and rapid drawdown of the water level. The presence of blue-green algae in large numbers and volumes gives an indication that aesthetic problems could occur. If these types of algae continue to increase until they reach nuisance proportions, they would also become a factor in restricting the use of the recreation around and on the reservoir.

That the biomass of the blue-green algae is not at nuisance levels now is due in part to the present operation of the reservoir. The withdrawal of water through low-level outlets and the time of year that it is released is working to the advantage of the reservoir by trapping and removing nutrients before they can become recycled. This in turn prevents increased productivity.

The levels at which the biomass of the blue-green algae become a source of complaints from water users have been determined by the

Department of Parks and Recreation. A survey of Clear Lake in Lake County made by Parks and Recreation in 1969 and 1970 shows that complaints by recreationists begin when the biomass volume of blue-green algae approaches 3 million cubic microns per milliliter (u^3ml) in the top meter of water. At 10 million u^3ml, about one of every four recreationists complained.

The highest volumes of blue-green algae measured in the top meter of water in East Park Reservoir was 1.1 million u^3ml. At that time (July 23, 1970) both soluble nitrogen and soluble phosphorus were depleted in the epilimnetic water. As nitrogen fixing species of blue-green algae were present, it can be assumed that further algal production was most likely limited by the depletion of phosphorus.

In formulating conclusions based on present knowledge and interpretation of the data collected, an estimate can be made on how much development can take place within the drainage basin without adversely affecting the water in the reservoir. For this report, this estimate is made using the following assumptions: first, an increase of the volume of algae by 2 million $u3/ml$ in the top meter during the highest measured peak of algal volumes during 1970 would begin to generate complaints by recreationists about the desirability of recreating in the reservoir. Second, that as nitrogen fixing blue-green algae were in abundance and as there was no available phosphorus present in the water column at that time, phosphorus was the limiting nutrient. Third, the chemical composition of the genera of blue-green algae present in the reservoir is similar to the composition of the same genera that have been analyzed by other scientists. These analyses show that the chemical composition of these genera is approximately 10 percent nitrogen and 1 percent phosphorus. Fourth, the average contribution of phosphorus to septic tank effluent is equal to one pound per contributor per year. Fifth, all of this phosphorus contribution would be in solution and could migrate into the epilimnetic waters of the reservoir at the time that the maximum bloom occurred and all of the phosphorus would be available for utilization by the blue-green algae.

Using these assumptions, it is estimated that to increase the algae volumes by 2 million $u3/ml$ in the 12,200 acre-feet of water in the epilimnion of the reservoir on July 23, 1970, would have required an addition of 660 pounds of phosphorus. This amount has a yearly population equivalent of 660 people. That is to say, if the yearly phosphorus contributions from 660 people were mixed into the epilimnetic waters on the above date, the blue-green algae would have increased their biomass volumes to the point where they would have created nuisance conditions for recreationists.

It is recognized that the phosphorus contributed to the watershed would not migrate to the reservoir at one date in time or that it would be evenly mixed in the epilimnetic waters; however, because of the uncertainty of determining the exact reaction of biological organisms in aquatic environments, this rationale allows a safety factor.

These conclusions then would indicate that if East Park Reservoir is continued to be operated as it has been in the past year, if

additional septic tanks and leach fields are engineered so that they can receive the expected load without failing, and if the waters continue to be used for their present purposes, then development can be permitted in the East Park Reservoir drainage, using the septic tank and leach field method for disposal of domestic wastes, the reservoir should be able to accept a phosphorus load equivalent to the amount 760 people would contribute annually.

If any of the above conditions change such as the schedule of operating the reservoir, or when the permanent population approaches the 760 mark, a reevaluation of their effects on the reservoir will have to be made.